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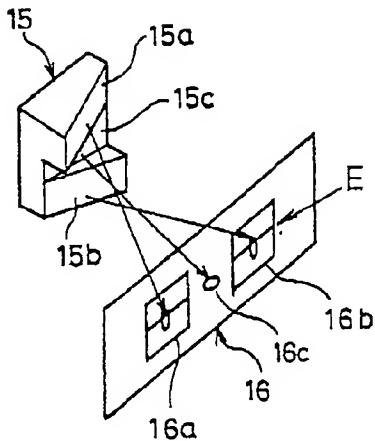
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(54) Optical information recording/reproducing apparatus.

(57) An optical information recording/reproducing apparatus records information on and/or reproduces information from an optical recording medium and detects a focal error based on a reflected light beam from the optical recording medium. The apparatus includes an optical element (15, 15A, 25, 25A, 85, 85A, 95, 95A, 105, 105A, 105B, 35, 45, 55) which deflects a part of the reflected light beam to at least two positions excluding a central part of the reflected light beam, and a photodetector device (16, 26, 36, 56, 66, 216A) having a plurality of photodetectors which respectively detect the deflected parts of the reflected light beam and output detection outputs. The focal error is detected based on the detection outputs of the photodetector device.

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## BACKGROUND OF THE INVENTION

The present invention generally relates to optical information recording/reproducing apparatuses, and more particularly to an optical information recording/reproducing apparatus which optically records information on a recording medium and/or optically reproduces the information from the recording medium.

An optical disk unit is an example of a unit which uses an optical information recording/reproducing apparatus. The optical disk unit can be used as a storage unit of a file system or the like, and is suited for storing programs and large amounts of data. In such an optical disk unit, it is desirable that an optical system thereof can accurately record and/or reproduce the information, and that the number of parts thereof is minimized so as to reduce the cost of the optical disk unit as a whole.

Various techniques have been proposed to detect a focal error in the optical disk unit. Generally, the astigmatism technique and the Foucault technique are well known. The Foucault technique is sometimes also referred to as the double knife edge technique.

Compared to the astigmatism technique, the Foucault technique is less affected by the external disturbance that occurs when a track on an optical disk is traversed, the birefringence of the optical disk. Accordingly, the mixture of the external disturbance into a focal error signal when the Foucault technique is employed is extremely small compared to the case where the astigmatism technique is employed. In addition, the Foucault technique detects a reflected light beam from the optical disk by a photodetector which is arranged in a vicinity of an image formation point of the optical beam, and for this reason, an abnormal offset is unlikely generated in the focal error signal even if the reflected light beam shifts from an optical axis. Because of these advantageous features obtainable by the Foucault technique, it is desirable to employ the Foucault technique as the focal error detection technique.

First, an example of an optical information recording/reproducing apparatus within a conventional magneto-optic disk unit which employs the Foucault technique will be described with reference to FIG. 1.

In an optical system of the optical information recording/reproducing apparatus shown in FIG. 1, a laser beam which is emitted from a laser diode 201 is formed into a parallel beam having an oval cross section in a collimator lens 202, and is thereafter formed into a light beam having a circular cross section in a true circle correction prism 203. The light beam from the true circle correction prism 203

is transmitted through a beam splitter 204, reflected by a mirror 205, and is converged on a disk 207 via an objective lens 206. A reflected light beam from the disk 207 enters the beam splitter 204 via the objective lens 206 and the mirror 205, but this time the reflected light beam is reflected by the beam splitter 204 and is directed towards a beam splitter 208. The beam splitter 208 splits the reflected light beam into two light beams, and supplies one light beam to a magneto-optic signal detection system and the other light beam to a servo signal detection system.

The magneto-optic signal detection system includes a Wollaston prism 209, a lens 210 and a 2-part photodetector 211. One of the two light beams output from the beam splitter 208 is input to the 2-part photodetector 211 via the Wollaston prism 209 and the lens 210, and the 2-part photodetector 211 detects the magneto-optic signal, that is, the information signal, based on the input light beam.

The servo signal detection system includes a condenser lens 212, a beam splitter 213, a 2-part photodetector 214, a composite prism 215 and a 4-part photodetector 216. The other of the two light beams output from the beam splitter 208 is input to the 2-part photodetector 214 via the condenser lens 212 and the beam splitter 213 on one hand, and is input to the 4-part photodetector 216 via the composite prism 215 on the other. The 2-part photodetector 214 forms a tracking error detection system in the servo signal detection system, and generates a tracking error signal by obtaining a difference between the outputs of the 2-part photodetector 214 according to the push-pull technique. The composite prism 215 and the 4-part photodetector 216 form a focal error detection system in the servo signal detection system, and generates a focal error signal based on outputs of the 4-part photodetector 216 according to the Foucault technique. A focus servo operation controls the relative positional relationship of the objective lens 206 and the disk 207 based on the focal error signal, so that an in-focus position is located on the disk 207.

Next, a description will be given of the push-pull technique, by referring to FIGS. 2 and 3. FIG. 2 shows the relative positional relationship of the light beam which is irradiated via the objective lens 206 and the track on the disk 207, and FIG. 3 shows a spot of the reflected light beam which is formed on the 2-part photodetector 214 in correspondence with FIG. 2.

In FIG. 2, (b) shows a case where the spot of the light beam is positioned at the center of a guide groove 207a of the disk 207. In this case, the spot of the reflected light beam on the 2-part photodetector 214 is formed as shown in FIG. 3 (b), and a light intensity distribution b is symmetrical to

the right and left. If the outputs of the 2-part photodetector 214 are denoted by A and B, a tracking error signal TES is generated based on the following formula (1).

$$TES = A - B \quad (1)$$

In this case, the tracking error signal TES is 0.

If the spot of the light beam in FIG.2 (b) shifts to the right as shown in FIG.2 (a), a light intensity distribution a of the reflected light beam becomes unbalanced and the light intensity at the left detector part of the 2-part photodetector 214 becomes larger as shown in FIG.3 (a). For this reason, the tracking error signal TES in this case takes a positive value.

On the other hand, if the spot of the light beam in FIG.2 (b) shifts to the left as shown in FIG.2 (c), a light intensity distribution c of the reflected light beam becomes unbalanced and the light intensity at the right detector part of the 2-part photodetector 214 becomes larger as shown in FIG.3 (c). For this reason, the tracking error signal TES in this case takes a negative value.

Accordingly, if the spot of the light beam on the disk 207 shifts to the right or left with respect to the central position of the guide groove 207a, the tracking error signal TES which is obtained in the above described manner changes to a more positive or negative value. Thus, it is possible to carry out an appropriate tracking control operation based on the tracking error signal TES.

FIG.4 shows an example of the shapes of the composite prism 215 and the 4-part photodetector 216. The 4-part photodetector 216 includes detector parts 216a, 216b, 216c and 216d. A focal error signal FES is generated from outputs A, B, C and D respectively output from the detector parts 216a, 216b, 216c and 216d of the 4-part photodetector 216, based on the following formula (2).

$$FES = (A-B) + (C-D) \quad (2)$$

Ideally, the focal error signal FES is 0 in a state where the spot of the light beam is in focus on the disk 207. In this case, the focal error signal FES having an S-curve as shown in FIG.5 is obtained depending on the distance between the objective lens 206 and the disk 207. In FIG.5, the ordinate indicates the focal error signal FES, and the abscissa indicates the distance between the objective lens 206 and the disk 207. The origin (0) on the abscissa corresponds to the in-focus position, and the above distance becomes smaller towards the left and larger towards the right in FIG.5.

FIG.6 shows the relative positional relationship of the objective lens 206 and the disk 207. In FIG.6, (a) shows a case where the objective lens

206 is close to the disk 207 and the in-focus position is located above the disk 207 in the figure, (b) shows a case where the in-focus position is located on the disk 207, and (c) shows a case where the objective lens 206 is far from the disk 207 and the in-focus position is located between the disk 207 and the objective lens 206 in the figure.

FIG.7 shows beam spots on the 4-part photodetector 216 for each relative positional relationship of the objective lens 206 and the disk 207 shown in FIG.6. In FIG.7, (a) shows the beam spots for the positional relationship shown in FIG.6 (a), (b) shows the beam spots for the in-focus positional relationship shown in FIG.6 (b), and (c) shows the beam spots for the positional relationship shown in FIG.6 (c). As shown in FIG.7 (b), the beam spots on the 4-part photodetector 216 have oval shapes in the in-focus position, and a division line E of the 4-part photodetector 216 is positioned at the center of each oval beam spot.

However, in the actual disk unit, the distribution of the quantity of the light beam irradiated on the disk 207 may be unbalanced, and errors may exist in the mounting positions of the composite prism 215 and the 4-part photodetector 216.

The light intensity distribution of the light beam which is emitted from the laser diode 201 can generally be approximated by a Gaussian distribution. Hence, if the optical axis of the light beam emitted from the laser diode 201 matches the optical axes of other optical parts, it is possible to obtain a Gaussian distribution in which the center of the light intensity of the light beam input to the objective lens 206 matches the optical axis (point 0) shown in FIG. 8. However, if the light beam emitted from the laser diode 201 is inclined by an angle  $\theta$  in FIG. 1, the center of the light intensity of the light beam input to the objective lens 206 is shifted from the optical axis (point 0) in the Gaussian distribution as indicated by a dotted line in FIG.8. The "unbalanced distribution" of the light quantity of the light beam irradiated on the disk 207 or "decentering", refers to such a difference between the optical axis and the center of light beam intensity distribution.

On the other hand, the "mounting error" of the composite prism 215, for example, refers to a positional error of the composite prism 215 in a y-direction in FIG.4. If such a mounting error exists, the composite prism 215 cannot accurately split the incident light beam into two equal light beams. Generally, if the center line of the composite prism 215 shifts a distance  $\Delta y$  in the y-direction from the center of the incident light beam, where the center line extends in the x-direction in FIG.4, the value of the mounting error can be obtained from  $[\Delta y / (\text{diameter of light beam})] \cdot 100 (\%)$ .

For this reason, if the quantity of the light beam which is split into two in the composite prism 215 changes and a positional error of the division line E of the 4-part photodetector 216 occurs, a focal offset is generated. The generation of the "focal offset" means that the focal error signal FES described by the formula (2) becomes 0 at a position other than the in-focus position. Thus, according to the conventional Foucault technique, the tolerable margin of the focal error detection system is extremely small with respect to the unbalanced distribution of the quantity of light beam irradiated on the disk 207, the mounting error of the composite prism 215 and the 4-part photodetector 216 and the like. Therefore, there is a problem in that it is extremely difficult to obtain an accurate focal error signal due to the above error factors.

#### SUMMARY OF THE INVENTION

Accordingly, it is a general object of the present invention to provide a novel and useful optical information recording/reproducing apparatus in which the problem described above is eliminated.

Another and more specific object of the present invention is to provide an optical information recording reproducing apparatus which records information on and/or reproduces information from an optical recording medium and detects a focal error based on a reflected light beam from the optical recording medium, comprising a composite prism deflecting a part of the reflected light beam to at least two positions excluding a central part of the reflected light beam, and photodetector means including a plurality of photodetectors for respectively detecting the deflected parts of the reflected light beam and outputting detection outputs, where the focal error is detected based on the detection outputs of the photodetector means. According to the optical information recording/reproducing apparatus of the present invention, it is possible to obtain an accurate focus error signal because the tolerable margin of the focus error detection system can be set large with respect to the unbalanced distribution of the quantity of the light beam irradiated on the optical recording medium, the mounting error of the composite prism, the photodetector and the like.

Still another object of the present invention is to provide an optical information recording/reproducing apparatus which records information on and/or reproduces information from an optical recording medium and detects a tracking error and a focal error based on a reflected light beam from the optical recording medium, comprising beam splitter means for splitting the reflected light beam into at least one first beam which is used for

detecting the tracking error and at least two second beams which are used for detecting the focal error, and photodetector means including a first photodetector which detects the first beam at a position other than an image formation point of the first beam, and second photodetectors for detecting the second beams approximately at image formation points of the second beams. According to the optical information recording/reproducing apparatus of the present invention, it is unnecessary to provide two independent optical paths even if the focal error is to be detected according to the Foucault technique and the tracking error is to be detected according to the push-pull technique. As a result, it is possible to reduce the space occupied by the optical system within the optical information recording/reproducing apparatus, and to reduce the number of required parts. For this reason, it is possible to reduce both the size and cost of the optical information recording/reproducing apparatus and an optical disk unit to which the optical information recording/reproducing apparatus may be applied.

A further object of the present invention is to provide an optical information recording/reproducing apparatus which records information on and/or reproduces information from an optical recording medium and detects a focal error and a tracking error based on a reflected light beam from the optical recording medium, comprising beam splitter means for splitting the reflected light beam into first through fourth light beams which propagate generally in a predetermined direction, and photodetector means for detecting the focal error in response to the first and second light beams, and for detecting the tracking error in response to the third and fourth light beams. According to the optical information recording/reproducing apparatus of the present invention, it is possible to improve the reliability of the focus error detection and tracking error detection. In addition, it is possible to reduce both the size and cost of the optical information recording/reproducing apparatus and an optical disk unit to which the optical information recording/reproducing apparatus may be applied.

Another object of the present invention is to provide an optical information recording/reproducing apparatus which records an information signal on and/or reproduces the information signal from an optical recording medium and detects a tracking error, a focal error, the information signal and an address signal based on a reflected light beam from the optical recording medium, comprising beam splitter means for splitting the reflected light beam into first through sixth light beams which propagate generally in a predetermined direction, and photodetector means for detecting the focal error in response to the first and second light

beams, and for detecting the tracking error, the information signal and the address signal in response to the third through sixth light beams. According to the optical information recording/reproducing apparatus of the present invention, it is possible to detect the focal error signal, the tracking error signal, the information signal and the address signal by the single photodetector means. For this reason, it is possible to detect all of the necessary signals using a single optical path to the beam splitter means and the single photodetector means. Hence, it is possible to reduce both the size and cost of the optical information recording/reproducing apparatus and an optical disk unit to which the optical information recording/reproducing apparatus may be applied.

Still another object of the present invention is to provide an optical information recording/reproducing apparatus which records information on and/or reproduces information from an optical recording medium and detects a focal error based on a reflected light beam from the optical recording medium, comprising an optical element deflecting a part of the reflected light beam to at least two positions excluding a central part of the reflected light beam, and photodetector means including a plurality of photodetectors for respectively detecting the deflected parts of the reflected light beam and outputting detection outputs, where the focal error is detected based on the detection outputs of the photodetector means. According to the optical information recording/reproducing apparatus of the present invention, it is possible to obtain an accurate focus error signal because the tolerable margin of the focus error detection system can be set large with respect to the unbalanced distribution of the quantity of the light beam irradiated on the optical recording medium, the mounting error of the composite prism, the photodetector and the like. For example, the optical element comprises a hologram optical element including a plurality of deflecting parts formed with hologram patterns, and the part of the reflected light beam excluding the central part of the reflected light beam is deflected to at least two positions by the deflecting parts.

Other objects and further features of the present invention will be apparent from the following detailed description when read in conjunction with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG.1 is a diagram showing an example of a conventional optical information recording/reproducing apparatus;  
 FIG.2 in parts (a), (b) and (c) is a diagram showing the relative positional relationship be-

5 tween a light beam which is irradiated via an objective lens and a track on an optical disk for explaining the push-pull technique;  
 FIG.3 in parts (a), (b) and (c) is a diagram showing a spot of a reflected light beam which is formed on a 2-part photodetector;  
 10 FIG.4 is a perspective view showing an example of the shapes of a composite prism and a 4-part photodetector;  
 FIG.5 is a diagram showing the relationship of a distance between the objective lens and the disk and a focal error signal FES;  
 FIG.6 in parts (a), (b) and (c) is a diagram showing the relative positional relationship of the objective lens and the disk;  
 15 FIG.7 in parts (a), (b) and (c) is a diagram showing a spot of a reflected light beam which is formed on the 4-part photodetector;  
 FIG.8 is a diagram showing a Gaussian distribution;  
 20 FIG.9 is a perspective view showing an essential part of a first embodiment of an optical information recording/reproducing apparatus according to the present invention;  
 FIG.10 is a perspective view showing an essential part of a second embodiment of the optical information recording/reproducing apparatus according to the present invention;  
 25 FIG.11 is a perspective view showing an essential part of a third embodiment of the optical information recording/reproducing apparatus according to the present invention;  
 FIG.12 is a perspective view showing an essential part of a fourth embodiment of the optical information recording/reproducing apparatus according to the present invention;  
 30 FIG.13 is a perspective view showing an essential part of a fifth embodiment of the optical information recording/reproducing apparatus according to the present invention;  
 FIG.14 is a perspective view showing an essential part of a sixth embodiment of the optical information recording/reproducing apparatus according to the present invention;  
 35 FIG.15 is a perspective view showing an essential part of a seventh embodiment of the optical information recording/reproducing apparatus according to the present invention;  
 FIG.16 is a perspective view showing an essential part of an eighth embodiment of the optical information recording/reproducing apparatus according to the present invention;  
 40 FIG.17 is a perspective view showing an essential part of a ninth embodiment of the optical information recording/reproducing apparatus according to the present invention;  
 FIG.18 is a perspective view showing an essential part of a tenth embodiment of the optical

information recording/reproducing apparatus according to the present invention;  
 FIG.19 is a cross sectional view showing an eleventh embodiment of the optical information recording/reproducing apparatus according to the present invention;  
 FIG.20 is a perspective view showing an essential part of the eleventh embodiment of the optical information recording/reproducing apparatus according to the present invention;  
 FIG.21 in parts (a), (b), (c) and (d) is a diagram showing simulation results describing the relationship of a focus position and a focal error signal FES in the prior art;  
 FIG.22 in parts (a), (b), (c) and (d) is a diagram showing simulation results describing the relationship of the focus position and the focal error signal FES in the first, third, fifth seventh, ninth or tenth embodiment;  
 FIG.23 is a diagram showing the relationship of a detector shift and a focal offset in the prior art;  
 FIG. 24 is a diagram showing the relationship of the detector shift and the focal offset in the first, third, fifth, seventh, ninth or tenth embodiment;  
 FIG. 25 is a diagram showing a twelfth embodiment of the optical information recording/reproducing apparatus according to the present invention;  
 FIG.26 in parts (a) and (b) is a diagram showing a composite prism of the twelfth embodiment on an enlarged scale;  
 FIG.27 is a perspective view showing an essential part of the twelfth embodiment;  
 FIG.28 in parts (a) and (b) is a diagram showing a composite prism of a thirteenth embodiment of the optical information recording/reproducing apparatus according to the present invention on an enlarged scale;  
 FIG.29 is a perspective view showing an essential part of the thirteenth embodiment;  
 FIG.30 in parts (a) and (b) is a diagram showing a composite prism of a fourteenth embodiment of the optical information recording/reproducing apparatus according to the present invention on an enlarged scale;  
 FIG.31 is a perspective view showing an essential part of the fourteenth embodiment;  
 FIG.32 is a diagram showing a fifteenth embodiment of the optical information recording/reproducing apparatus according to the present invention;  
 FIG.33 is a perspective view showing an essential part of the fifteenth embodiment;  
 FIG.34 is a plan view showing a photodetector of the fifteenth embodiment;  
 FIG.35 is a perspective view showing an essential part of a sixteenth embodiment of the optical information recording/reproducing apparatus ac-

5 cording to the present invention;  
 FIG.36 is a cross sectional view showing an essential part of a hologram optical element of the sixteenth embodiment;  
 FIG.37 is a perspective view for explaining the functions of the hologram optical element by itself;  
 FIG.38 is a plan view for explaining the construction of the hologram optical element;  
 FIG.39 is a cross sectional view showing an essential part of a hologram optical element of a seventeenth embodiment of the optical information recording/reproducing apparatus according to the present invention;  
 FIG.40 is a perspective view for explaining desirable functions of the hologram optical element by itself;  
 FIG.41 is a diagram showing an eighteenth embodiment of the optical information recording/reproducing apparatus according to the present invention;  
 FIG.42 in parts (a) and (b) is a diagram showing a composite prism of the eighteenth embodiment;  
 FIG.43 is a perspective view showing an essential part of the eighteenth embodiment;  
 FIG.44 is a diagram showing a nineteenth embodiment of the optical information recording/reproducing apparatus according to the present invention;  
 FIG.45 is a perspective view showing a Wollaston prism of the nineteenth embodiment;  
 FIG.46 is a diagram showing an integral part made up of a composite prism and the Wollaston prism of the nineteenth embodiment; and  
 FIG.47 is a perspective view showing an essential part of the nineteenth embodiment.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

40 FIG.9 is a perspective view showing an essential part of a first embodiment of an optical information recording/reproducing apparatus according to the present invention. A composite prism 15 includes tapered parts 15a and 15b, and a central part 15c having no taper. On the other hand, a 4-part photodetector 16 includes 2-part photodetectors 16a and 16b, and a central part 16c which includes no photodetector part. The composite prism 15 and the 4-part photodetector 16 are provided in place of the composite prism 215 and the 4-part photodetector 216 in the optical system of the optical information recording/reproducing apparatus shown in FIG.1, for example, and detect the focal error.

45 The reflected light beam which is obtained via the beam splitters 204 and 208, the condenser lens

212 and the beam splitter 213 is input to the composite prism 15. Out of the reflected light beam which is input to the composite prism 15, the light beams transmitted through the tapered parts 15a and 15b of the composite prism 15 form spots on the corresponding 2-part photodetectors 16a and 16b of the 4-part photodetector 16. Accordingly, by carrying out the operation of the formula (2) described above using the outputs of the 2-part photodetectors 16a and 16b, it is possible to obtain a focal error signal FES similarly to the conventional case.

On the other hand, out of the reflected light beam, the light beam which is transmitted through the central part 15c of the composite prism 15 is input to the central part 16c of the 4-part photodetector 16. As a result, out of the reflected light beam input to the composite prism 15, the light beam which is transmitted through the central part 15c of the composite prism 15 is not input to the 2-part photodetectors 16a and 16b of the 4-part photodetector 16, that is, not input to a light sensitive part of the 4-part photodetector 16.

In this embodiment, the spots which are formed on the 2-part photodetectors 16a and 16b of the 4-part photodetector 16 have oval shapes with a major axis greater than that of the conventional case. In other words, the oval spots are longer in a direction perpendicular to the division line E of each of the 2-part photodetectors 16a and 16b. For this reason, the focal offset which is generated by the positional error of the division lines E is extremely small.

Next, a description will be given of a second embodiment of the optical information recording/reproducing apparatus according to the present invention, by referring to FIG.10. FIG.10 is a perspective view showing an essential part of the second embodiment.

In FIG.10, a composite prism 25 has a trapezoidal column shape and includes tapered parts 25a and 25b, and a central part 25c which has no taper. On the other hand, a 4-part photodetector 26 includes 2-part photodetectors 26a and 26b, and a central part 26c which includes no photodetector part. The composite prism 25 and the 4-part photodetector 26 are provided in place of the composite prism 215 and the 4-part photodetector 216 in the optical system of the optical information recording/reproducing apparatus shown in FIG.1, for example, and detect the focal error.

The reflected light beam which is obtained via the beam splitters 204 and 208, the condenser lens 212 and the beam splitter 213 is input to the composite prism 25. Out of the reflected light beam which is input to the composite prism 25, the light beams transmitted through the tapered parts

25a and 25b of the composite prism 25 form spots on the corresponding 2-part photodetectors 26a and 26b of the 4-part photodetector 26. Accordingly, by carrying out the operation of the formula (2) described above using the outputs of the 2-part photodetectors 26a and 26b, it is possible to obtain a focal error signal FES similarly to the conventional case.

On the other hand, out of the reflected light beam, the light beam which is transmitted through the central part 25c of the composite prism 25 is input to the central part 26c of the 4-part photodetector 26. As a result, out of the reflected light beam input to the composite prism 25, the light beam which is transmitted through the central part 25c of the composite prism 25 is not input to the 2-part photodetectors 26a and 26b of the 4-part photodetector 26, that is, not input to a light sensitive part of the 4-part photodetector 26.

In this embodiment, the spots which are formed on the 2-part photodetectors 26a and 26b of the 4-part photodetector 26 have oval shapes with a major axis greater than that of the conventional case. In other words, the oval spots are longer in a direction perpendicular to the division line E of each of the 2-part photodetectors 26a and 26b. For this reason, the focal offset which is generated by the positional error of the division lines E is extremely small.

Next, a description will be given of a third embodiment of the optical information recording/reproducing apparatus according to the present invention, by referring to FIG.11. FIG.11 is a perspective view showing an essential part of the third embodiment. In FIG.11, those parts which are the same as those corresponding parts in FIG.9 are designated by the same reference numerals, and a description thereof will be omitted.

In this embodiment, a light absorbing or blocking layer 15cA is formed on the central part 15c of a composite prism 15A so as to absorb or block the light beam which has the wavelength of the light emitted from the laser diode 201 shown in FIG.1. This light absorbing or blocking layer 15cA may be formed on the front surface or the rear surface of the composite prism 15A at the central part 15c. In addition, this embodiment uses the same 4-part photodetector 216 used in the conventional case shown in FIG.1.

In this case, the reflected light beam which is obtained via the beam splitters 204 and 208, the condenser lens 212 and the beam splitter 213 is input to the composite prism 15A. Out of the reflected light beam which is input to the composite prism 15A, the light beams transmitted through the tapered parts 15a and 15b of the composite prism 15A form spots on the corresponding detector parts 216a, 216b, 216c and 216d of the 4-part

photodetector 216. Accordingly, by carrying out the operation of the formula (2) described above using the outputs of the detector parts 216a, 216b, 216c and 216d, it is possible to obtain a focal error signal FES similarly to the conventional case.

On the other hand, out of the reflected light beam, the light beam which is input to the central part 15c of the composite prism 15A is absorbed or blocked light absorbing or blocking layer 15cA and will not be input to the 4-part photodetector 216. As a result, out of the reflected light beam input to the composite prism 15A, the light beam which is input to the central part 15c of the composite prism 15A is not input to the detector parts 216a, 216b, 216c and 216d of the 4-part photodetector 216, that is, not input to a light sensitive part of the 4-part photodetector 216.

In this embodiment, the spots which are formed on the detector parts 216a, 216b, 216c and 216d of the 4-part photodetector 216 have oval shapes with a major axis greater than that of the conventional case. In other words, the oval spots are longer in a direction perpendicular to the division line E of the 4-part photodetector 216. For this reason, the focal offset which is generated by the positional error of the division line E is extremely small.

Next, a description will be given of a fourth embodiment of the optical information recording/reproducing apparatus according to the present invention, by referring to FIG.12. FIG.12 is a perspective view showing an essential part of the fourth embodiment. In FIG.12, those parts which are the same as those corresponding parts in FIG.10 are designated by the same reference numerals, and a description thereof will be omitted.

In this embodiment, a light absorbing or blocking layer 25cA is formed on the central part 25c of a composite prism 25A which has a triangular prism shape, so as to absorb or block the light beam which has the wavelength of the light emitted from the laser diode 201 shown in FIG.1. This light absorbing or blocking layer 25cA may be formed on the front surface or the rear surface of the composite prism 25A at the central part 25c. In addition, this embodiment uses a 4-part photodetector 216A shown in FIG.12.

In this case, the reflected light beam which is obtained via the beam splitters 204 and 208, the condenser lens 212 and the beam splitter 213 is input to the composite prism 25A. Out of the reflected light beam which is input to the composite prism 25A, the light beams transmitted through the tapered parts 25a and 25b of the composite prism 25A form spots on the corresponding detector parts 216a, 216b, 216c and 216d of the 4-part photodetector 216A. Accordingly, by carrying out the operation of the formula (2) described above

using the outputs of the detector parts 216a, 216b, 216c and 216d, it is possible to obtain a focal error signal FES similarly to the conventional case.

On the other hand, out of the reflected light beam, the light beam which is transmitted through the central part 25c of the composite prism 25A is absorbed or blocked light absorbing or blocking layer 25cA and will not be input to the 4-part photodetector 216A. As a result, out of the reflected light beam input to the composite prism 25A, the light beam which is input to the central part 25c of the composite prism 25A is not input to the detector parts 216a, 216b, 216c and 216d of the 4-part photodetector 216A, that is, not input to a light sensitive part of the 4-part photodetector 216A.

In this embodiment, the spots which are formed on the detector parts 216a, 216b, 216c and 216d of the 4-part photodetector 216A have oval shapes with a major axis greater than that of the conventional case. In other words, the oval spots are longer in a direction perpendicular to the division lines E of the 4-part photodetector 216A. For this reason, the focal offset which is generated by the positional error of the division lines E is extremely small.

Next, a description will be given of a fifth embodiment of the optical information recording/reproducing apparatus according to the present invention, by referring to FIG.13. FIG.13 is a perspective view showing an essential part of this fifth embodiment. In FIG.13, those parts which are the same as those corresponding parts in FIG.9 are designated by the same reference numerals, and a description thereof will be omitted.

In FIG.13, a hologram optical element 85 includes lattice forming parts 85a and 85b having the lattice shape or structure, and a central part 85c having no lattice shape or structure. The hologram optical element 85 and the 4-part photodetector 16 are provided in place of the composite prism 215 and the 4-part photodetector 216 and detect the focal error in the optical system of the optical information recording/reproducing apparatus shown in FIG.1, for example.

In other words, when this embodiment is applied to the optical system shown in FIG.1, the reflected light beam obtained via the beam splitters 204 and 208, the condenser lens 212 and the beam splitter 213 becomes incident to the hologram optical element 85. Out of this reflected light beam incident to the hologram optical element 85, the light beams transmitted through the lattice forming parts 85a and 85b of the hologram optical element 85 respectively form spots on the 2-part photodetectors 16a and 16b of the 4-part photodetector 16. Accordingly, it is possible to obtain the focal error signal FES similarly to the

conventional case by carrying out the operation of the formula (2) described above using the outputs of the 2-part photodetectors 16a and 16b.

Out of the reflected light beam incident to the hologram optical element 85, the light beam transmitted through the central part 85c of the hologram optical element 85 becomes incident to the central part 16c of the 4-part photodetector 16. As a result, the light beam transmitted through the central part 85c of the hologram optical element 85 will not become incident to the 2-part photodetectors 16a and 16b of the 4-part photodetector 16, that is, will not become incident to the photosensitive part of the 4-part photodetector 16.

According to this embodiment, the spots formed on the 2-part photodetectors 16a and 16b of the 4-part photodetector 16 have oval shapes with a relatively large major axis when compared to the conventional case described above. In other words, the oval spots formed on the 2-part photodetectors 16a and 16b of the 4-part photodetector 16 are long in the direction perpendicular to the division lines E of the corresponding 2-part photodetectors 16a and 16b. For this reason, the focal offset which is generated by the positional error of the division lines E can be made extremely small.

Next, a description will be given of a sixth embodiment of the optical information recording/reproducing apparatus according to the present invention, by referring to FIG.14. FIG.14 is a perspective view showing an essential part of this sixth embodiment. In FIG.14, those parts which are the same as those corresponding parts in FIG.10 are designated by the same reference numerals, and a description thereof will be omitted.

In FIG.14, a hologram optical element 95 includes lattice forming parts 95a and 95b having the lattice shape or structure, and a central part 95c having no lattice shape or structure. The hologram optical element 95 and the 4-part photodetector 26 are provided in place of the composite prism 215 and the 4-part photodetector 216 and detect the focal error in the optical system of the optical information recording/reproducing apparatus shown in FIG.1, for example.

In other words, when this embodiment is applied to the optical system shown in FIG.1, the reflected light beam obtained via the beam splitters 204 and 208, the condenser lens 212 and the beam splitter 213 becomes incident to the hologram optical element 95. Out of this reflected light beam incident to the hologram optical element 95, the light beams transmitted through the lattice forming parts 95a and 95b of the hologram optical element 95 respectively form spots on the 2-part photodetectors 26a and 26b of the 4-part photodetector 26. Accordingly, it is possible to ob-

tain the focal error signal FES similarly to the conventional case by carrying out the operation of the formula (2) described above using the outputs of the 2-part photodetectors 26a and 26b.

Out of the reflected light beam incident to the hologram optical element 95, the light beam transmitted through the central part 95c of the hologram optical element 95 becomes incident to the central part 26c of the 4-part photodetector 26. As a result, the light beam transmitted through the central part 95c of the hologram optical element 95 will not become incident to the 2-part photodetectors 26a and 26b of the 4-part photodetector 26, that is, will not become incident to the photosensitive part of the 4-part photodetector 26.

According to this embodiment, the spots formed on the 2-part photodetectors 26a and 26b of the 4-part photodetector 26 have oval shapes with a relatively large major axis when compared to the conventional case described above. In other words, the oval spots formed on the 2-part photodetectors 26a and 26b of the 4-part photodetector 26 are long in the direction perpendicular to the division lines E of the corresponding 2-part photodetectors 26a and 26b. For this reason, the focal offset which is generated by the positional error of the division lines E can be made extremely small.

Next, a description will be given of a seventh embodiment of the optical information recording/reproducing apparatus according to the present invention, by referring to FIG.15. FIG.15 is a perspective view showing an essential part of this seventh embodiment. In FIG.15, those parts which are the same as those corresponding parts in FIGS.11 and 13 are designated by the same reference numerals, and a description thereof will be omitted.

In FIG.15, a layer 85cA is formed at a central part 85c of a hologram optical element 85A. This layer 85cA absorbs or blocks the light beam having the wavelength of the light beam emitted from the laser diode 201 in the optical system of the optical information recording/reproducing apparatus shown in FIG.1. This layer 85cA may be formed on the front surface or the rear surface of the hologram optical element 85A at the central part 85c.

In other words, when this embodiment is applied to the optical system shown in FIG.1, the reflected light beam obtained via the beam splitters 204 and 208, the condenser lens 212 and the beam splitter 213 becomes incident to the hologram optical element 85A. Out of this reflected light beam incident to the hologram optical element 85A, the light beams transmitted through the lattice forming parts 85a and 85b of the hologram optical element 85A respectively form spots on the detector parts 216a and 216b and the detector parts

216c and 216d of the 4-part photodetector 216. Accordingly, it is possible to obtain the focal error signal FES similarly to the conventional case by carrying out the operation of the formula (2) described above using the outputs of the detector parts 216a, 216b, 216c and 216d.

Out of the reflected light beam incident to the hologram optical element 85A, the light beam incident to the central part 85c of the hologram optical element 85A is absorbed or blocked by the layer 85cA and will not become incident to the 4-part photodetector 216. As a result, the light beam incident to the central part 85c of the hologram optical element 85A will not become incident to the detector parts 216a, 216b, 216c and 216d of the 4-part photodetector 216, that is, will not become incident to the photosensitive part of the 4-part photodetector 216.

According to this embodiment, the spots formed on the detector parts 216a and 216b and the detector parts 216c and 216d of the 4-part photodetector 216 have oval shapes with a relatively large major axis when compared to the conventional case described above. In other words, the oval spots formed on the detector parts 216a and 216b and the detector parts 216c and 216d of the 4-part photodetector 216 are long in the direction perpendicular to the division lines E of the corresponding pair of detector parts 216a and 216b and pair of detector parts 216c and 216d. For this reason, the focal offset which is generated by the positional error of the division lines E can be made extremely small.

Next, a description will be given of an eighth embodiment of the optical information recording/reproducing apparatus according to the present invention, by referring to FIG.16. FIG.16 is a perspective view showing an essential part of this eighth embodiment. In FIG.16, those parts which are the same as those corresponding parts in FIGS.12 and 14 are designated by the same reference numerals, and a description thereof will be omitted.

In FIG.16, a layer 95cA is formed at a central part 95c of a hologram optical element 95A. This layer 95cA absorbs or blocks the light beam having the wavelength of the light beam emitted from the laser diode 201 in the optical system of the optical information recording/reproducing apparatus shown in FIG.1. This layer 95cA may be formed on the front surface or the rear surface of the hologram optical element 95A at the central part 95c.

In other words, when this embodiment is applied to the optical system shown in FIG.1, the reflected light beam obtained via the beam splitters 204 and 208, the condenser lens 212 and the beam splitter 213 becomes incident to the hologram optical element 95A. Out of this reflected light

beam incident to the hologram optical element 95A, the light beams transmitted through the lattice forming parts 95a and 95b of the hologram optical element 95A respectively form spots on the detector parts 216a and 216b and the detector parts 216c and 216d of the 4-part photodetector 216A. Accordingly, it is possible to obtain the focal error signal FES similarly to the conventional case by carrying out the operation of the formula (2) described above using the outputs of the detector parts 216a, 216b, 216c and 216d.

Out of the reflected light beam incident to the hologram optical element 95A, the light beam incident to the central part 95c of the hologram optical element 95A is absorbed or blocked by the layer 95cA and will not become incident to the 4-part photodetector 216A. As a result, the light beam incident to the central part 95c of the hologram optical element 95A will not become incident to the detector parts 216a, 216b, 216c and 216d of the 4-part photodetector 216A, that is, will not become incident to the photosensitive part of the 4-part photodetector 216A.

According to this embodiment, the spots formed on the detector parts 216a and 216b and the detector parts 216c and 216d of the 4-part photodetector 216A have oval shapes with a relatively large major axis when compared to the conventional case described above. In other words, the oval spots formed on the detector parts 216a and 216b and the detector parts 216c and 216d of the 4-part photodetector 216A are long in the direction perpendicular to the division lines E of the corresponding pair of detector parts 216a and 216b and pair of detector parts 216c and 216d. For this reason, the focal offset which is generated by the positional error of the division lines E can be made extremely small.

Next, a description will be given of a ninth embodiment of the optical information recording/reproducing apparatus according to the present invention, by referring to FIG.17. FIG.17 is a perspective view showing an essential part of this ninth embodiment.

In FIG.17, a hologram optical element 105 includes lattice forming parts 105a, 105b, 105c and 105d having the lattice shape or structure. On the other hand, a 6-part photodetector 217 includes detector parts 217a, 217b, 217c and 217d which form a 4-part photodetector, and detector parts 217e and 217f arranged above and below this 4-part photodetector.

When the reflected light beam from the disk is irradiated on the hologram optical element 105, the light beams transmitted through the lattice forming parts 105a and 105b respectively form spots on the detector parts 217a and 217b and the detector parts 217c and 217d which form the 4-part

photodetector of the 6-part photodetector 217. In addition, the light beams transmitted through the lattice forming parts 105c and 105d of the hologram optical element 105 respectively form spots on the detector parts 217e and 217f of the 6-part photodetector 217. Accordingly, it is possible to obtain the focal error signal FES similarly to the conventional case by carrying out the operation of the formula (2) described above using the outputs of the detector parts 217a, 217b, 217c and 217d. On the other hand, it is possible to obtain the tracking error signal TES similarly to the conventional case by carrying out the operation of the formula (1) described above using the outputs of the detector parts 217e and 217f.

When this embodiment is applied to the optical system shown in FIG.1, the hologram optical element 105 and the 6-part photodetector 217 are provided in place of the composite prism 215 and the 4-part photodetector 216, to detect the focal error. At the same time, it is possible to also detect the tracking error, and for this reason, it is possible to omit the beam splitter 213 and the 2-part photodetector 214.

Out of the reflected light beam incident to the hologram optical element 105, the light beams incident to the lattice forming parts 105c and 105d at the central part of the hologram optical element 105 respectively become incident to the detector parts 217e and 217f of the 6-part photodetector 217. As a result, the light beams transmitted through the central part of the hologram optical element 105 will not become incident to the detector parts 217a, 217b, 217c and 217d which form the 4-part photodetector of the 6-part photodetector 217, that is, will not become incident to the part of the 6-part photodetector 217 for obtaining the focal error.

According to this embodiment, the spots formed on the detector parts 217a and 217b and the detector parts 217c and 217d forming the 4-part photodetector of the 6-part photodetector 217 have oval shapes with a relatively large major axis when compared to the conventional case described above. In other words, the oval spots formed on the detector parts 217a and 217b and the detector parts 217c and 217d of the 4-part photodetector are long in the direction perpendicular to the division lines E of the corresponding pair of detector parts 217a and 217b and pair of detector parts 217c and 217d. For this reason, the focal offset which is generated by the positional error of the division lines E can be made extremely small.

Next, a description will be given of a tenth embodiment of the optical information recording/reproducing apparatus according to the present invention, by referring to FIG.18. FIG.18 is a perspective view showing an essential part of this

ninth embodiment. In FIG.18, those parts which are the same as those corresponding parts in FIG.17 are designated by the same reference numerals, and a description thereof will be omitted.

In FIG.18, a hologram optical element 105A includes lattice forming parts 105a, 105b, 105cA and 105dA having the lattice shape or structure. On the other hand, a 6-part photodetector 217A includes detector parts 217a, 217b, 217c and 217d which form a 4-part photodetector, and detector parts 217eA and 217fA arranged on the right and left of this 4-part photodetector.

When the reflected light beam from the disk is irradiated on the hologram optical element 105A, the light beams transmitted through the lattice forming parts 105a and 105b respectively form spots on the detector parts 217a and 217b and the detector parts 217c and 217d which form the 4-part photodetector of the 6-part photodetector 217A. In addition, the light beams transmitted through the lattice forming parts 105cA and 105dA of the hologram optical element 105A respectively form spots on the detector parts 217eA and 217fA of the 6-part photodetector 217A. Accordingly, it is possible to obtain the focal error signal FES similarly to the conventional case by carrying out the operation of the formula (2) described above using the outputs of the detector parts 217a, 217b, 217c and 217d. On the other hand, it is possible to obtain the tracking error signal TES similarly to the conventional case by carrying out the operation of the formula (1) described above using the outputs of the detector parts 217eA and 217fA.

When this embodiment is applied to the optical system shown in FIG.1, the hologram optical element 105A and the 6-part photodetector 217A are provided in place of the composite prism 215 and the 4-part photodetector 216, to detect the focal error. At the same time, it is possible to also detect the tracking error, and for this reason, it is possible to omit the beam splitter 213 and the 2-part photodetector 214.

Out of the reflected light beam incident to the hologram optical element 105A, the light beams incident to the lattice forming parts 105cA and 105dA at the central part of the hologram optical element 105A respectively become incident to the detector parts 217eA and 217fA of the 6-part photodetector 217A. As a result, the light beams transmitted through the central part of the hologram optical element 105A will not become incident to the detector parts 217a, 217b, 217c and 217d which form the 4-part photodetector of the 6-part photodetector 217A, that is, will not become incident to the part of the 6-part photodetector 217A for obtaining the focal error.

According to this embodiment, the spots formed on the detector parts 217a and 217b and

the detector parts 217c and 217d forming the 4-part photodetector of the 6-part photodetector 217A have oval shapes with a relatively large major axis when compared to the conventional case described above. In other words, the oval spots formed on the detector parts 217a and 217b and the detector parts 217c and 217d of the 4-part photodetector are long in the direction perpendicular to the division lines E of the corresponding pair of detector parts 217a and 217b and pair of detector parts 217c and 217d. For this reason, the focal offset which is generated by the positional error of the division lines E can be made extremely small.

Next, a description will be given of an eleventh embodiment of the optical information recording/reproducing apparatus according to the present invention, by referring to FIGS.19 and 20. FIG.19 shows a cross sectional view of this eleventh embodiment, and FIG.20 shows a perspective view of an essential part of this eleventh embodiment. In FIGS.19 and 20, those parts which are the same as those corresponding parts in FIG.17 are designated by the same reference numerals, and a description thereof will be omitted.

In FIG.19, a laser diode chip 201A, the 6-part photodetector 217 and a hologram optical element 105B are mounted on a common housing 218. The hologram optical element 105B has the same functions as the hologram optical element 105 shown in FIG.17, but the 6-part photodetector 217 is arranged at a position shifted in the direction Y in FIG.19 from a center of an optical axis of the optical system. For this reason, the deflecting direction of the light beam incident to the 6-part photodetector 217 needs to be shifted in the same direction Y to match the arrangement of the 6-part photodetector 217. Hence, the hologram patterns of the hologram optical element 105B is slightly different from the hologram pattern of the hologram optical element 105 shown in FIG.17.

The light beam which is emitted from the laser diode chip 201A in the direction Z in FIG. 19 first becomes incident to the hologram optical element 105B. In general, the light beam incident to a hologram optical element is separated into a 0th order light,  $\pm 1$ st order lights and high order lights. The 0th order light is the light beam which passes through the hologram optical element 105B as it is. Hence, the 0th order light is transmitted through a beam splitter 204A and becomes incident to an objective lens 206A, and is converged as a minute point on the disk 207. The reflected light beam from the disk 207 is transmitted through the objective lens 206A and becomes incident again to the beam splitter 204A. A part of the reflected light beam is reflected by the beam splitter 204A towards a magneto-optic signal detection system which is made up of a Wollaston prism 209A and a

2-part photodetector 211A, and a magneto-optic signal is detected. On the other hand, a part of the reflected light beam transmitted through the beam splitter 204A becomes incident to the hologram optical element 105B, and is again separated into the 0th order light, the  $\pm 1$ st order lights and the high order lights.

In this embodiment, the  $+1$ st order light or the  $-1$ st order light obtained by the second separation is used as the light for detecting the servo signal. For example, the  $+1$ st order light emitted from a part 105aB of the hologram optical element 105B is received by the detector parts 217a and 217b, and the  $+1$ st order light emitted from a part 105bB of the hologram optical element 105B is received by the detector parts 217c and 217d. In addition, the  $+1$ st order light emitted from a part 105cB of the hologram optical element 105B is received by the detector part 217e, and the  $+1$ st order light emitted from a part 105dB of the hologram optical element 105B is received by the detector part 105f. Accordingly, it is possible to obtain the focal error signal FES similarly to the conventional case by carrying out the operation of the formula (2) described above using the outputs of the detector parts 217a, 217b, 217c and 217d forming the 4-part photodetector of the 6-part photodetector 217. On the other hand, it is possible to obtain the tracking error signal TES similarly to the conventional case by carrying out the operation of the formula (1) described above using the outputs of the detector parts 217e and 217f.

According to this embodiment, it is possible to reduce the volume (that is, the size) of the apparatus as a whole when compared to the conventional case shown in FIG.1. Furthermore, it is possible to reduce the cost and improve the reliability of the apparatus by reducing the number of parts that are required.

FIG.21 shows simulation results describing the relationship of the focal position and the focal error signal FES in the prior art shown in FIG.4. In FIG.21, a bold solid line indicates a case where a detector shift is 0, a solid line indicates a case where the detector shift is  $+10 \mu\text{m}$ , a dotted line indicates a case where the detector shift is  $+20 \mu\text{m}$ , a bold dotted line indicates a case where the detector shift is  $-10 \mu\text{m}$ , and a bold and fine dotted line indicates a case where the detector shift is  $-20 \mu\text{m}$ . The "detector shift" refers to the shift of the division line E of the 4-part photodetector 216 in the y-direction in FIG.4, and an upward shift in FIG.4 is taken as a positive (+) shift and a downward shift in FIG.4 is taken as a negative (-) shift.

In FIG.21, (a) shows a case where the mounting error of the composite prism 215 is 5%, (b) shows a case where the mounting error is 10%, (c) shows a case where the inclination angle  $\theta$  of the

light beam emitted from the laser diode 201 is  $0.5^\circ$ , and (d) shows a case where the inclination angle  $\theta$  of the light beam emitted from the laser diode 201 is  $1.0^\circ$ . The case where the inclination angle  $\theta$  is  $0.5^\circ$  corresponds to the case where the shift of the light beam from the optical axis at the objective lens 206 is 0.25 mm, and the case where the inclination angle  $\theta$  is  $1.0^\circ$  corresponds to the case where the shift of the light beam from the optical axis at the objective lens 206 is 0.50 mm. Accordingly, if the detector shift indicated by the dotted line in FIG.21 (a) is  $+20 \mu\text{m}$ , for example, it may be seen that a focal offset of approximately  $2.0 \mu\text{m}$  is generated.

On the other hand, FIG.22 shows simulation results describing the relationship of the focal position and the focal error signal FES in the first embodiment shown in FIG.9, the third embodiment shown in FIG.11, the fifth embodiment shown in FIG.13, the seventh embodiment shown in FIG.15, the ninth embodiment shown in FIG.17, the tenth embodiment shown in FIG.18 or, the eleventh embodiment shown in FIGS.19 and 20. In FIG.22, a bold solid line indicates a case where the detector shift is 0, a solid line indicates a case where the detector shift is  $+10 \mu\text{m}$ , a dotted line indicates a case where the detector shift is  $+20 \mu\text{m}$ , a bold dotted line indicates a case where the detector shift is  $-10 \mu\text{m}$ , and a bold and fine dotted line indicates a case where the detector shift is  $-20 \mu\text{m}$ .

In FIG.22, (a) shows a case where the mounting error of the composite prism 15 or 15A or the hologram optical element 85, 85A, 105, 105A or 105B is 5%, (b) shows a case where the mounting error is 10%. (c) shows a case where the inclination angle  $\theta$  of the light beam emitted from the laser diode 201 is  $0.5^\circ$ , and (d) shows a case where the inclination angle  $\theta$  of the light beam emitted from the laser diode 201 is  $1.0^\circ$ . The case where the inclination angle  $\theta$  is  $0.5^\circ$  corresponds to the case where the shift of the light beam from the optical axis at the objective lens 206 is 0.25 mm, and the case where the inclination angle  $\theta$  is  $1.0^\circ$  corresponds to the case where the shift of the light beam from the optical axis at the objective lens 206 is 0.50 mm. Accordingly, even if the detector shift indicated by the dotted line in FIG.22 (a) is  $+20 \mu\text{m}$ , for example, it may be seen that only an extremely small focal offset of approximately  $0.8 \mu\text{m}$  is generated. In other words, the focal offset is less than one-half the focal offset of the conventional case.

FIG.23 is a diagram showing the relationship of the detector shift and the focal offset in the prior art based on the simulation results of FIG.21. In FIG.23, a coarse dotted line shows a case where the mounting error of the composite prism 215 is 5%, a fine dotted line indicates a case where the

mounting error of the composite prism 215 is 10%, a two-dot chain line indicates a case where the shift of the light beam from the optical axis at the objective lens 206 is 0.25 mm, and a one-dot chain line indicates a case where the shift of the light beam from the optical axis at the objective lens 206 is 0.50 mm. As may be seen from FIG.23, the focal offset is generated in each case where the detector shift occurs.

On the other hand, FIG.24 is a diagram showing the relationship of the detector shift and the focal offset in the first, third, fifth, seventh, ninth, tenth or eleventh embodiment based on the simulation results of FIG.22. In FIG.24, a coarse dotted line shows a case where the mounting error of the composite prism 15 or 15A or the hologram optical element 85, 85A, 105, 105A or 105B is 5%, a fine dotted line indicates a case where the mounting error of the composite prism 15 or 15A is 10%, a two-dot chain line indicates a case where the shift of the light beam from the optical axis at the objective lens 206 is 0.25 mm, and a one-dot chain line indicates a case where the shift of the light beam from the optical axis at the objective lens 206 is 0.50 mm. As may be seen from FIG.24, the focal offset which is generated is extremely small or approximately 0 in each case where the detector shift occurs. Accordingly, it can be seen that the focal offset in the first, third, fifth, seventh, ninth, tenth or eleventh embodiment is extremely small compared to that of the prior art.

In FIG.1, the arrangement of the 4-part photodetector 216 along the optical axis must be set approximately to the image formation point position of the condenser lens 212, due to the operating principle of the Foucault technique. On the other hand, the arrangement of the 2-part photodetector 214 along the optical axis must be set at a position shifted from the image formation point position of the condenser lens 212, due to the operating principle of the push-pull technique. In other words, the 2-part photodetector 214 must be set at the so-called far field.

For the above reasons, it is necessary to split the reflected light beam into two by use of the beam splitter 213, and independently provide an optical path which is used to carry out the Foucault technique and an optical path which is used to carry out the push-pull technique. As a result, if the focal error is to be detected using the Foucault technique and the tracking error is to be detected using the push-pull technique, the optical system occupies a relatively large space because of the need to provide two independent optical paths, and furthermore, the number of parts required becomes large.

Accordingly, a description will hereinafter be given of embodiments of the optical information

recording/reproducing apparatus according to the present invention which reduce the space of the optical system occupying within the optical information recording/reproducing apparatus and reduce the number of required parts, so that the size and cost of the optical information recording/reproducing apparatus and the optical disk unit using the same can both be reduced.

First, a description will be given of a twelfth embodiment of the optical information recording/reproducing apparatus according to the present invention, by referring to FIGS.25 through 27. In FIG.25, those parts which are the same as those corresponding parts in FIG.1 are designated by the same reference numerals, and a description thereof will be omitted.

In this embodiment, it is unnecessary to provide the beam splitter 213 and the 2-part photodetector 214 shown in FIG.1, as may be seen from FIG.25. In addition, a composite prism 35 and a photodetector 36 are provided in place of the composite prism 215 and the 4-part photodetector 216. In other words, this embodiment uses the central part of the reflected light beam which is not used in the first through fourth embodiments, for detecting the tracking error by the push-pull technique.

FIG.26 shows the composite prism 35 on an enlarged scale. In FIG.26, (a) shows a perspective view of the composite prism 35, and (b) shows a plan view of the composite prism 35. As shown in FIG.26, the composite prism 35 includes tapered first and second parts 35a and 35b, and a third part 35c which has a convex surface with a slight curvature. Hence, a reflected light beam 30 which is obtained via the beam splitter 208 is split into three light beams 30a, 30b and 30c.

FIG.27 is a perspective view, on an enlarged scale, showing an essential part of FIG.25. The photodetector 36 includes a first photodetector 36a, a second photodetector 36b, and a third photodetector 36c. The first photodetector 36a includes photodetectors 37a and 37b. The second photodetector 36b includes photodetectors 37c and 37d. The third photodetector 36c includes photodetectors 37e and 37f.

Out of the reflected light beam 30 which is refracted and condensed via the condenser lens 212, the light beam 30a which is transmitted through the first part 35a is deflected depending on the taper angle of the first part 35a and is irradiated on the first photodetector 36a of the photodetector 36, while the light beam 30b which is transmitted through the second part 35b is deflected depending on the taper angle of the second part 35b and is irradiated on the second photodetector 36b of the photodetector 36. In addition, the light beam 30c which is transmitted through the third part 35c

is refracted depending on the curvature of the third part 35c and is irradiated on the third photodetector 36c of the photodetector 36. In other words, the light beams 30a and 30b are only subjected to the refraction function of the condenser lens 212, but the light beam 30c is subjected to the refraction function of the condenser lens 212 and the third part 35c itself. Therefore, image formation points 300a and 300b of the respective light beams 30a and 30b are different from an image formation point 300c of the light beam 30c. That is, distances L1 and L2 from the condenser lens 212 to the image formation points 300a and 300b of the respective light beams 30a and 30b are different from a distance L3 from the condenser lens 212 to the image formation point 300c of the light beam 30c.

In FIG.27, the photodetector 36 is arranged on a plane which is perpendicular to the optical axis of the reflected light beam 30 and includes the image formation points 300a and 300b. Because of this arrangement, the first and second photodetectors 36a and 36b which are used to generate the focal error signal FES based on the Foucault technique are respectively provided at the positions of the image formation points 300a and 300b of the light beams 30a and 30b. On the other hand, the third photodetector 36c which is used to generate the tracking error signal TES based on the push-pull technique is provided at a position deviated from the position of the image formation point 300c of the light beam 30c. Hence, it is possible to generate the focal error signal FES using the Foucault technique and to generate the tracking error signal TES using the push-pull technique by use of a simple optical system. The generation itself of the focal error signal FES and the tracking error signal TES may be made similarly to the prior art, and a description thereof will be omitted.

The requirement is that the distances L1 and L2 between the condenser lens 212 and the respective image formation points 300a and 300b of the light beams 30a and 30b are different from the distance L3 between the condenser lens 212 and the image formation point 300c of the light beam 30c, and the construction and arrangement of the composite prism 35 and the photodetector 36 are not limited to those of the above embodiment.

Next, a description will be given of a thirteenth embodiment of the optical information recording/reproducing apparatus according to the present invention, by referring to FIGS.28 and 29. In FIGS.28 and 29, those parts which are the same as those corresponding parts in FIGS.26 and 27 are designated by the same reference numerals, and a description thereof will be omitted.

In this embodiment, a composite prism 45 shown in FIG.28 is used in place of the composite

prism 35 shown in FIG.26.

FIG.28 shows the composite prism 45 on an enlarged scale. In FIG.28, (a) shows a perspective view of the composite prism 45, and (b) shows a plan view of the composite prism 45. As shown in FIG.28, the composite prism 45 includes tapered first and second parts 45a and 45b, and a third part 45c which has a concave surface with a slight curvature. Hence, a reflected light beam 30 which is obtained via the beam splitter 208 is split into three light beams 30a, 30b and 30c.

FIG.29 is a perspective view, on an enlarged scale, showing an essential part of this embodiment. The photodetector 36 is the same as the photodetector 36 used in the twelfth embodiment.

Out of the reflected light beam 30 which is refracted and condensed via the condenser lens 212, the light beam 30a which is transmitted through the first part 45a is deflected depending on the taper angle of the first part 45a and is irradiated on the first photodetector 36a of the photodetector 36, while the light beam 30b which is transmitted through the second part 45b is deflected depending on the taper angle of the second part 45b and is irradiated on the second photodetector 36b of the photodetector 36. In addition, the light beam 30c which is transmitted through the third part 45c is refracted depending on the curvature of the third part 45c and is irradiated on the third photodetector 36c of the photodetector 36. In other words, the light beams 30a and 30b are only subjected to the refraction function of the condenser lens 212, but the light beam 30c is subjected to the refraction function of the condenser lens 212 and the third part 45c itself. Therefore, image formation points 300a and 300b of the respective light beams 30a and 30b are different from an image formation point 300c of the light beam 30c. That is, distances L1 and L2 from the condenser lens 212 to the image formation points 300a and 300b of the respective light beams 30a and 30b are different from a distance L3 from the condenser lens 212 to the image formation point 300c of the light beam 30c.

In other words, the image formation point 300c of the light beam 30c is located between the composite prism 35 and the photodetector 36 in the twelfth embodiment, but the image formation point 300c of the light beam 30c in this embodiment is located beyond the photodetector 36 in FIG.29 along the traveling direction of the light beam.

In FIG.29, the photodetector 36 is arranged on a plane which is perpendicular to the optical axis of the reflected light beam 30 and includes the image formation points 300a and 300b, similarly to the twelfth embodiment shown in FIG.27. Because of this arrangement, the first and second photodetectors 36a and 36b which are used to generate the

focal error signal FES based on the Foucault technique are respectively provided at the positions of the image formation points 300a and 300b of the light beams 30a and 30b. On the other hand, the third photodetector 36c which is used to generate the tracking error signal TES based on the push-pull technique is provided at a position deviated from the position of the image formation point 300c of the light beam 30c. Hence, it is possible to generate the focal error signal FES using the Foucault technique and to generate the tracking error signal TES using the push-pull technique by use of a simple optical system.

Next, a description will be given of a fourteenth embodiment of the optical information recording/reproducing apparatus according to the present invention, by referring to FIGS.30 and 31. In FIGS.30 and 31, those parts which are the same as those corresponding parts in FIGS.26 and 27 are designated by the same reference numerals, and a description thereof will be omitted.

In this embodiment, a composite prism 55 and a photodetector 56 shown in FIG.31 are used in place of the composite prism 35 and the photodetector 36 shown in FIG.26.

FIG.30 shows the composite prism 55 on an enlarged scale. In FIG.30, (a) shows a perspective view of the composite prism 55, and (b) shows a plan view of the composite prism 55. As shown in FIG.30, the composite prism 55 includes tapered first and second parts 55a and 55b, and a flat third part 55c which has not taper. Hence, a reflected light beam 30 which is obtained via the beam splitter 208 is split into three light beams 30a, 30b and 30c.

FIG.31 is a perspective view, on an enlarged scale, showing an essential part of this embodiment. The photodetector 56 includes a first photodetector 56a, a second photodetector 56b, and a third photodetector 56c. The first photodetector 56a includes photodetectors 37a and 37b. The second photodetector 56b includes photodetectors 37c and 37d. The third photodetector 56c includes photodetectors 37e and 37f. The third photodetector 56c is arranged on a plane different from a plane on which the first and second photodetectors 56a and 56b are arranged.

Out of the reflected light beam 30 which is refracted and condensed via the condenser lens 212, the light beam 30a which is transmitted through the first part 55a is deflected depending on the taper angle of the first part 55a and is irradiated on the first photodetector 56a of the photodetector 56, while the light beam 30b which is transmitted through the second part 55b is deflected depending on the taper angle of the second part 55b and is irradiated on the second photodetector 56b of the photodetector 56. In addition, the light beam

30c which is transmitted through the third part 55c is transmitted as it is and is irradiated on the third photodetector 56c of the photodetector 56. In other words, all of the light beams 30a, 30b and 30c are only subjected to the refraction function of the condenser lens 212. Therefore, image formation points 300a, 300b and 300c of the respective light beams 30a, 30b and 30c are all located on the same plane. That is, distances L1, L2 and L3 from the condenser lens 212 to the image formation points 300a, 300b and 300c of the respective light beams 30a, 30b and 30c are the same. However, since the third photodetector 56c in this embodiment is arranged on the plane which is different from the plane on which the first and second photodetectors 56a and 56b are arranged, the image formation point 300c of the light beam 30c and the position of the third photodetector 56c do not match.

In other words, the image formation point 300c of the light beam 30c is located between the composite prism 35 and the photodetector 36 in the twelfth embodiment, but the image formation point 300c of the light beam 30c in this embodiment is located beyond the third photodetector 56c. In FIG.31 along the traveling direction of the light beam.

In FIG 31, the first and second photodetectors 56a and 56b of the photodetector 56 are arranged on a plane which is perpendicular to the optical axis of the reflected light beam 30 and includes the image formation points 300a and 300b, similarly to the twelfth embodiment shown in FIG.27. Because of this arrangement, the first and second photodetectors 56a and 56b which are used to generate the focal error signal FES based on the Foucault technique are respectively provided at the positions of the image formation points 300a and 300b of the light beams 30a and 30b. On the other hand, the third photodetector 56c which is used to generate the tracking error signal TES based on the push-pull technique is provided at a position deviated from the position of the image formation point 300c of the light beam 30c. Hence, it is possible to generate the focal error signal FES using the Foucault technique and to generate the tracking error signal TES using the push-pull technique by use of a simple optical system.

The generation of the focal error signal FES based on the Foucault technique is not limited to that of the embodiment using two light beams, and it is of course possible to use more than two light beams for the generation of the focal error signal FES. Similarly, the generation of the tracking error signal TES based on the push-pull technique is not limited to that of the embodiment using one light beam, and it is of course possible to use more than one light beam for the generation of the tracking

error signal TES.

Next, a description will be given of a fifteenth embodiment of the optical information recording/reproducing apparatus according to the present invention, by referring to FIGS.32, 33 and 34. In FIGS.32 and 33, those parts which are the same as those corresponding parts in FIG.25 are designated by the same reference numerals, and a description thereof will be omitted.

5 In this embodiment, an analyzer 208A shown in FIGS.32 and 33 is used together with the composite prism 35 and the photodetector 36 shown in FIG.25.

10 In this embodiment, an analyzer 21 disclosed in a Japanese Laid-Open Patent Application No. 63-127436 may be used as the analyser 208A. In this fifteenth embodiment, the light beam is split into three light beams by the analyser 208A, and each of the three light beams are further split into three 15 light beams by the composite prism 35, thereby resulting in nine ( $3 \times 3 = 9$ ) light beams being output from the composite prism 35. The nine light beams from the composite prism 35 are irradiated on corresponding ones of nine photodetectors 66a through 66i which form the photodetector 66.

20 FIG.34 shows a plan view of the photodetector 66. The focal error signal FES can be generated according to the Foucault technique based on outputs of the photodetectors 66a, 66b, 66d, 66e, 66g and 66h of the photodetector 66. The photodetectors 66a, 66d and 66g receive the three light beams from the first part of the composite prism 35, while the photodetectors 66b, 66e and 66h receive the three light beams from the second part 25 of the composite prism 35. The image formation points of these six light beams match the positions of the photodetectors 66a, 66b, 66d, 66e, 66g and 66h. On the other hand, the tracking error signal TES can be generated according to the push-pull technique based on outputs of the photodetectors 66c, 66f and 66i. The photodetectors 66c, 66f and 66i receive the three light beams from the third part of the composite prism 35. The image formation points of these three light beams are deviated 30 from the positions of the photodetectors 66a, 66f and 66i.

35 As shown in FIG.34, the photodetector 66a includes photodetector parts 37a and 37b, the photodetector 66b includes photodetector parts 37c and 37d, ..., and the photodetector 66i includes photodetector parts 37q and 37r. Accordingly, if the outputs of these photodetector parts 37a through 37i are denoted by the same reference numerals as these parts, the focal error signal FES using the Foucault technique can be generated based on the 40 following formula (3) by calculation.

$$FES = [(37a) + (37g) + (37m) + (37d) + (37j) + (37p)] -$$

$$[(37b) + (37h) + (37n) + (37c) + (37i) + (37o)] \quad (3)$$

In addition, the tracking error signal using the push-pull technique can be generated based on the following formula (4) by calculation.

$$\text{TES} = [(37e) + (37k) + (37q)] - [(37f) + (37l) + (37r)] \quad (4)$$

Furthermore, by the function of the analyzer 208A, a magneto-optic signal (information signal) RF which is recorded on the disk 207 can be reproduced based on the following formula (5) by calculation.

$$\text{RF} = [(37a) + (37b) + (37e) + (37f) + (37c) + (37d)] - [(37m) + (37n) + (37q) + (37r) + (37o) + (37p)] \quad (5)$$

According to the fifteenth embodiment, the magneto-optic signal detection system and the servo signal detection signal can be provided approximately on a single optical path, and it is therefore possible to further reduce both the size and cost of the optical information recording/reproducing apparatus compared to the twelfth through fourteenth embodiments. As is evident from a comparison of FIGS.25 and 32, the Wollaston prism 209, the lens 210 and the 2-part photodetector 211 required in FIG 25 are omitted in FIG.32.

In the twelfth through fifteenth embodiments, the image formation point of the light beam used to generate the focal error signal FES according to the Foucault technique and the image formation point of the light beam used to generate the tracking error signal TES according to the push-pull technique are made mutually different by use of the composite prism. However, the method of making the image formation points of the light beams mutually different is not limited to that using the composite prism, and it is also possible to use a hologram optical element, for example.

Next, a description will be given of a sixteenth embodiment of the optical information recording/reproducing apparatus according to the present invention, by referring to FIGS. 35 and 36. In FIGS.35 and 36, those parts which are the same as those corresponding parts in FIG.27 are designated by the same reference numerals, and a description thereof will be omitted.

In this embodiment, a hologram optical element 75 shown in FIG.35 is used in place of the composite prism 35 shown in FIG.27.

FIG.35 is a perspective view showing an essential part of this embodiment on an enlarged scale. The hologram optical element 75 includes first and second parts 75a and 75b. The cross sectional shape of the first part 75a along a line A-A' in FIG.35 is a sawtooth grating as shown in

FIG.36. The second part 75b has a cross sectional shape similar to that of the first part 75a, but the cross sectional shape of the second part 75b is in point symmetry to that of the first part 75a with respect to the center of the hologram optical element 75. The sawtooth gratings of the first and second parts 75a and 75b are sometimes also referred to as blazed gratings.

The hologram optical element 75 separates the reflected light beam 30 into 0th order diffracted light,  $\pm 1$ st order diffracted lights, and high-order diffracted lights of  $\pm 2$ nd order or higher. In this embodiment, the cross sectional shape of the hologram optical element 75 is designed so that the effect of high-order diffracted lights of  $\pm 2$ nd order or higher are small when detecting the light. With regard to the  $\pm 1$ st order diffracted lights, the above described sawtooth cross sectional shapes of the first and second parts 75a and 75b are designed so that, for example, the quantity of the emitted  $+1$ st order diffracted light is larger than that of the emitted  $-1$ st order diffracted light, that is, so that the effects of the  $-1$ st order diffracted light which is a divergent ray is minimized.

Accordingly, this embodiment uses a  $+1$ st order diffracted light 30-1 which is diffracted by the grating of the first part 75a, a  $+1$ st order diffracted light 30-2 which is diffracted by the grating of the second part 75b, and a 0th order diffracted light 30-3 which passes through the first and second parts 75a and 75b without being affected by the gratings thereof. In addition, the grating patterns of the first and second parts 75a and 75b are designed such that the  $+1$ st order diffracted light 30-1 which is emitted from the first part 75a is refracted twice via the condenser lens 212 and the first port 75a before being imaged at an image formation point 300a, and the  $+1$ st order diffracted light 30-2 which is emitted from the second part 75b is refracted twice via the condenser lens 212 and the second part 75b before being imaged at an image formation point 300b. On the other hand, since the 0th order diffracted light 30-3 passes through the hologram optical element 75 as it is without being affected by the grating patterns, the 0th order diffracted light 30-3 is refracted only by the condenser lens 212 and is imaged at an image formation point 300c.

In FIG.35, the photodetector 36 is arranged on a plane which is perpendicular to the optical axis of the reflected light beam and includes the image formation points 300a and 300b. Because of this arrangement, the first and second photodetectors 36a and 36b which are used to generate the focal error signal FES based on the Foucault technique are respectively provided at the positions of the image formation points 300a and 300b of the  $+1$ st order diffracted lights 30-1 and 30-2. On the other

hand, the third photodetector 36c which is used to generate the tracking error signal TES based on the push-pull technique is provided at a position deviated from the position of the image formation point 300c of the 0th order diffracted light 30-3. Hence, it is possible to generate the focal error signal FES using the Foucault technique and to generate the tracking error signal TES using the push-pull technique by use of a simple optical system. The generation itself of the focal error signal FES and the tracking error signal TES may be made similarly to the prior art, and a description thereof will be omitted.

The requirement is that the distances L1 and L2 between the condenser lens 212 and the respective image formation points 300a and 300b of the +1st order diffracted lights 30-1 and 30-2 are different from the distance L3 between the condenser lens 212 and the image formation point 300c of the 0th order diffracted light 30-3, and the construction and arrangement of the hologram optical element 75 and the photodetector 36 are not limited to those of this embodiment.

Next, a description will be given of the functions of the hologram optical element 75 by itself, that is, for the case where no condenser lens 212 exists, by referring to FIGS.37 through 39.

As described above, the hologram optical element 75 includes the first and second parts 75a and 75b which are provided with independent patterns for deflecting, converging and diverging the light. More particularly, the patterns of the first and second parts 75a and 75b are respectively set so that the +1st order diffracted light 30-1 from the first part 75a converges to a point P'(-x, 0) and the +1st order diffracted light 30-2 from the second part 75b converges to a point P(x, 0). Points P and P' are located on a plane  $\pi$  which is a distance f away from the hologram optical element 75 along the optical axis. In other words, the function of the first part 75a is to image the parallel incident light at a focal point O at a focal distance f, and to converge the light to the point P' by deflecting the light by a distance x in the negative x-direction.

FIG.38 shows a plan view of the hologram optical element 75. Since the patterns of the first and second parts 75a and 75b are in point symmetry with respect to the origin O in FIG.38, the pattern of the first part 75a, for example, is made up of concentric grooves or projections having a center at the point P'(-x, 0). A radius  $r_i$  of an  $i$ th concentric groove or projection can be obtained from the following formula (6), where  $\lambda$  denotes the wavelength of the light output from the light source.

$$r_i = \sqrt{(2 \cdot f \cdot \lambda \cdot i)} \quad (6)$$

In addition, the cross sectional shape of the

first part 75a is determined so that the ratios of the 0th order diffracted light and the +1st order diffracted light with respect to the total quantity of light become predetermined values.

5 In the above sixteenth embodiment, the cross sectional shape of the hologram optical element 75 is designed so that the effects of the high-order diffracted lights of ±2nd order diffracted lights or higher are small when detecting the light. In addition, with respect to the ±1st order diffracted lights, the cross sectional shapes of the first and second parts 75a and 75b of the hologram optical element 75 are set to the sawtooth shape shown in FIG.36 so that the quantity of the emitted +1st order diffracted light is larger than that of the emitted -1st order diffracted light, that is, so that the effects of the -1st order diffracted light which is a divergent ray are minimized. However, it is of course possible to design the cross sectional shape of the hologram optical element 75 so that the quantity of the emitted -1st order diffracted light is larger than that of the emitted +1st order diffracted light, that is, so that the -1st order diffracted light which is a divergent ray is positively used and the effects of the +1st order diffracted light are minimized.

10 In a seventeenth embodiment of the optical information recording/reproducing apparatus according to the present invention, the hologram optical element 75 used has a cross sectional shape shown in FIG.39 along the line A-A' in FIG.35. An essential part of this embodiment is essentially the same as FIG.35, and an illustration thereof will be omitted. Contrary to the sixteenth embodiment, this embodiment positively uses the -1st order diffracted lights. For this reason, the first and second photodetectors 36a and 36b for generating the focal error signal FES based on the Foucault technique are provided at the image formation points of the -1st order diffracted lights. On the other hand, the third photodetector 36c for generating the tracking error signal TES based on the push-pull technique is provided at a position deviated from the image formation point 300c of the 0th order diffracted light, that is, between the hologram optical element 75 and the photodetector 36. As a result, it is possible to generate the focal error signal FES using the Foucault technique and to generate the tracking error signal TES using the push-pull technique by use of a simple optical system.

15 According to the structure shown in FIG.37, the +1st order diffracted light obtained from the first part 75a of the hologram optical element 75 may overlap the -1st order diffracted light obtained from the second part 75b, and the -1st order diffracted light obtained from the first part 75a may overlap the +1st order diffracted light obtained from the second part 75b. For this reason, the hologram

optical element 75 may be constructed so that by itself the hologram optical element 75 acts on the light as shown in FIG.40. In FIG.40, those parts which are the same as those corresponding parts in FIG.37 are designated by the same reference numerals, and a description thereof will be omitted.

In FIG.40, the patterns of the first and second parts 75a and 75b are set so that the +1st order diffracted light 30-1 from the first part 75a converges to a point Q'(-x, y), the -1st order diffracted light from the first part 75a is projected in a semi-circular shape about a point R'(x, -y), the +1st order diffracted light 30-2 from the second part 75b converges to a point Q(x, y), and the -1st order diffracted light is projected in a semicircular shape about a point R(-x, -y). The points Q, Q', R and R' are located on the plane  $\pi$  which is the distance f from the hologram optical element 75 along the optical axis.

Next, a description will be given of an eighteenth embodiment of the optical information recording/reproducing apparatus according to the present invention, by referring to FIGS.41 through 43. FIG.41 shows the eighteenth embodiment, FIG.42 shows a composite prism of the eighteenth embodiment, and FIG.43 shows a perspective view of an essential part of the eighteenth embodiment. In FIG.41, those parts which are the same as those corresponding parts in FIG.25 are designated by the same reference numerals, and a description thereof will be omitted.

In this embodiment, the spot of the light beam irradiated on the disk 207 via the objective lens 206 has a diameter of approximately 1  $\mu\text{m}$ , for example. In addition, the outputs of the 2-part photodetector 211 are used to generate an address signal ADR via an adder 311A, and the outputs of the 2-part photodetector 211 are also used to reproduce the magneto-optic signal (information signal) RF via a differential amplifier 311B.

In this embodiment, a composite prism 85 splits the reflected light beam which is obtained via the condenser lens 212 into first through fourth light beams 87a through 87d. These first through fourth light beams 87a through 87d are irradiated on a photodetector 86. The photodetector 86 includes a first photodetector 86a which has 4 light receiving parts A through D for receiving the first and second light beams 87a and 87b, a second photodetector 86b which has a light receiving part E for receiving the third light beam 87c, and a third photodetector 86c which has a light receiving part F for receiving the fourth light beam 87d. As shown in FIG.43, the first, second and third photodetectors 86a, 86b and 86c are arranged on the same plane. The first through third photodetectors 86a through 86c may or may not be separated from each other within the photodetector 86.

In FIG.42, (a) shows a perspective view of the composite prism 85 on an enlarged scale, and (b) shows a plan view of the composite prism 85. As shown, the composite prism 85 includes a first emission surface 85a for emitting the first light beam 87a, a second emission surface 85b for emitting the second light beam 87b, and third and fourth emission surfaces 85c and 85d for respectively emitting the third and fourth light beams 87c and 87d. In FIG.42 (a), the first emission surface 85a has a downward inclination to the right, the second emission surface 85b has a downward inclination to the left, and the third and fourth emission surfaces 85c and 85d form a mountain shape. In other words, the third emission surface 85c has a downward inclination to the right, the fourth emission surface 85d has a downward inclination to the left, and the third and fourth emission surfaces 85c and 85d connect to form the mountain shape.

The first emission surface 85a and the third emission surface 85c are inclined towards the same direction, and an inclination angle  $\alpha_1$  of the first emission surface 85a relative to a reference plane is smaller than an inclination angle  $\alpha_3$  of the third emission surface 85c. For example, the reference plane is the back surface of the composite prism 85, which is approximately perpendicular to the traveling direction of the incoming reflected light beam. On the other hand, the second emission surface 85b and the fourth emission surface 85d are inclined towards the same direction, and an inclination angle  $\alpha_2$  of the second emission surface 85b is smaller than an inclination angle  $\alpha_4$  of the fourth emission surface 85d.

In FIG.43, the first light beam 87a which is emitted from the first emission surface 85a of the composite prism 85 is received by the light receiving parts A and D of the first photodetector 86a. In addition, the second light beam 87b which is emitted from the second emission surface 85b of the composite prism 85 is received by the light receiving parts B and C of the first photodetector 86a. Hence, a focal error signal FES is generated according to the Foucault technique based on the formula (2) described above. More particularly, the outputs of the light receiving parts A and C are added in an adder 321, the outputs of the light receiving parts B and D are added in an adder 322, and the outputs of these adders 321 and 322 are supplied to a differential amplifier 323 which outputs the focal error signal FES.

On the other hand, the third light beam 87c which is emitted from the third emission surface 85c of the composite prism 85 is received by the light receiving part E of the second photodetector 86b, and the fourth light beam 87d which is emitted from the fourth emission surface 85d of the composite prism 85 is received by the light receiving

part F of the third photodetector 86c. Hence, a tracking error signal TES is generated according to the push-pull technique based on the formula (1) described above. More particularly, the outputs of the light receiving parts E and F are supplied to a differential amplifier 331, and the tracking error signal TES is output from this differential amplifier 331.

According to this embodiment, it is unnecessary to split the optical path into two by the beam splitter 213 shown in FIG.1, even though the Foucault technique is used to generate the focal error signal FES and the push-pull technique is used to generate the tracking error signal TES. For this reason, it is possible to reduce the space occupied by the optical system within the optical information recording/reproducing apparatus. In addition, it is possible to reduce both the number of parts and the cost of the optical information recording reproducing apparatus because this embodiment does not require the beam splitter 213 and the photodetector 214 shown in FIG.1. Furthermore, compared to the case where the astigmatism technique is used to generate the focal error signal FES, it is possible to reduce the diameter of the beam spot formed on the photodetector and prevent effects of the external disturbance, thereby making it possible to improve the reliability of the optical information recording/reproducing apparatus.

Moreover, if the photodetector 86 is adjusted to detect a predetermined focal error signal FES, it is possible to employ a structure that would automatically receive the third light beam 87c by the light receiving part E of the photodetector 86b and receive the fourth light beam 87d by the light receiving part F of the photodetector 86c. Hence, there is an additional advantage in that no adjustment is required in this case for the detection of the tracking error signal TES.

Next, a description will be given of a nineteenth embodiment of the optical information recording reproducing apparatus according to the present invention, by referring to FIGS.44 through 47. FIG.44 shows the nineteenth embodiment, and in FIG.44, those parts which are the same as those corresponding parts in FIG.41 are designated by the same reference numerals, and a description thereof will be omitted.

In this embodiment, an integral part 90 is provided in place of the composite prism 85 shown in FIG.41. In addition, the beam splitter 208, the Wollaston prism 209, the condenser lens 210 and the photodetector 211 shown in FIG.41 are not provided in FIG.44.

The reflected light beam which is obtained via the beam splitter 204 is converted by the condenser lens 212 and is input to the integral part 90

which functions as a beam splitter means. Hence, the reflected light beam is split into first through sixth light beams 91a through 91f, and these first through sixth light beams 91a through 91f are irradiated on a photodetector 86A.

The integral part 90 integrally comprises a Wollaston prism 92 shown in FIG.45 and the composite prism 85 shown in FIG.42. In other words, the Wollaston prism 92 is positioned immediately before the composite prism 85 along the traveling direction of a reflected light beam 89, and is adhered on the back of the composite prism 85 as shown in FIGS.46 and 47.

The Wollaston prism 92 is made up of two triangular prisms 93 and 94 which are cut from a crystal and adhered together. The size of the Wollaston prism 92 corresponds to the central mountain shaped part of the composite prism 85. The Wollaston prism 92 is adhered on the back of the composite prism 85 immediately behind a mountain part 85e of the composite prism 85. In addition, the Wollaston prism 92 extends for the full width of the mounting part 85e. Hence, the Wollaston prism 92 splits the incoming reflected light beam in a direction in which a vortex 85f of the mountain part 85e extends.

On the other hand, the photodetector 86A includes a first photodetector 86Aa, a second photodetector 86Ab-1, a third photodetector 86Ab-2, a fourth photodetector 86Ac-1 and a fifth photodetector 86Ac-2 which are provided on a single plane as shown in FIG.47. The first photodetector 86Aa includes four light receiving parts A through D for receiving the first and second light beams 91a and 91b. The second photodetector 86Ab-1 includes a light receiving part E<sub>1</sub> for receiving the third light beam 91c, and the third photodetector 86Ab-2 includes a light receiving part E<sub>2</sub> for receiving the fourth light beam 91d. The fourth photodetector 86Ac-1 includes a light receiving part F<sub>1</sub> for receiving the fifth light beam 91e, and the fifth photodetector 86Ac-2 includes a light receiving part F<sub>2</sub> for receiving the sixth light beam 91f.

Out of the reflected light beam 89 which is input to the integral part 90 via the condenser lens 212, a light component 89-1 which passes above the upper part of the Wollaston prism 92 in FIG.46 and reaches the composite prism 85 directly is refracted by the first emission surface 85a and is emitted from the first emission surface 85a as the first light beam 91a. As shown in FIG.47, this first light beam 91a is received by the light receiving parts A and D of the first photodetector 86Aa.

On the other hand, out of the reflected light beam 89 which is input to the integral part 90 via the condenser lens 212, a light component 89-2 which passes below the lower part of the Wollaston

prism 92 in FIG.46 and reaches the composite prism 85 directly is refracted by the second emission surface 85b and is emitted from the second emission surface 85b as the second light beam 91b. As shown in FIG.47, this second light beam 91b is received by the light receiving parts B and C of the first photodetector 86Aa.

A focal error signal FES is generated according to the Foucault technique based on the formula (2) described above, similarly to the eighteenth embodiment shown in FIG.41.

Out of the reflected light beam 89 which is input to the integral part 90 via the condenser lens 212, a light component 89-3 which reaches the Wollaston prism 92 is split into a p-wave 95 and an s-wave 96. The p-wave 95 is deflected by an angle  $\beta$  with respect to an extension line 97 of the light component 89-3 towards the first emission surface 85a. On the other hand, the s-wave 96 is deflected by an angle  $\beta$  with respect to the extension line 97 towards the second emission surface 85b.

The p-wave 95 and the s-wave 96 output from the Wollaston prism 92 is input to the composite prism 85. The angle  $\beta$  is small, and the p-wave 95 and the s-wave 96 propagate within the mountain part 85e of the composite prism 85. The p-wave 95 and the s-wave 96 reach the third and fourth emission surfaces 85c and 85d and are refracted thereby, and are thereafter emitted from the third and fourth emission surfaces 85c and 85d.

In other words, in FIG.47 the p-wave 95 is emitted from the third emission surface 85c as the third light beam 91c. This third light beam 91c irradiates the light receiving part E<sub>1</sub> of the second photodetector 86Ab-1. On the other hand, the s-wave 96 is emitted from the third emission surface 85c as the fourth light beam 91d. This fourth light beam 91d irradiates the light receiving part E<sub>2</sub> of the third photodetector 86Ab-2.

Similarly in FIG.47, p-wave 95 is emitted from the fourth emission surface 85d as the fifth light beam 91e. This fifth light beam 91e irradiates the light receiving part F<sub>1</sub> of the fourth photodetector 86Ac-1. On the other hand, the s-wave 96 is emitted from the fourth emission surface 85e as the sixth light beam 91f. This sixth light beam 91f irradiates the light receiving part F<sub>2</sub> of the fifth photodetector 86Ac-2.

A tracking error signal TES is obtained based on the outputs of the light receiving parts E<sub>1</sub>, E<sub>2</sub>, F<sub>1</sub> and F<sub>2</sub> of the second through fifth photodetectors 86Ab-1 through 86Ac-2. More particularly, the tracking error signal TES is obtained through adders 332 and 333 and the differential amplifier 331 shown in FIG.47, by calculating TES = (E<sub>1</sub> + E<sub>2</sub>) - (F<sub>1</sub> + F<sub>2</sub>).

In addition a magneto-optic signal (information signal) RF is obtained based on the outputs of the

light receiving parts E<sub>1</sub>, E<sub>2</sub>, F<sub>1</sub> and F<sub>2</sub> of the second through fifth photodetectors 86Ab-1 through 86Ac-2. More particularly, the magneto-optic signal RF is obtained through adders 312 and 313, and the differential amplifier 311B shown in FIG.47, by calculating RF = (E<sub>1</sub> + F<sub>1</sub>) - (E<sub>2</sub> + F<sub>2</sub>).

Furthermore, an address signal ADR is obtained based on the outputs of the light receiving parts E<sub>1</sub>, E<sub>2</sub>, F<sub>1</sub> and F<sub>2</sub> of the second through fifth photodetectors 86Ab-1 through 86Ac-2. More particularly, the address signal ADR is obtained through the adder 332, the adder 333, and the adder 311A shown in FIG.47, by calculating ADR = (E<sub>1</sub> + E<sub>2</sub>) + (F<sub>1</sub> + F<sub>2</sub>).

According to this embodiment, it is possible to detect all of the focal error signal FES, the tracking error signal TES, the magneto-optic signal RF and the address signal ADR by use of a single optical path of the reflected light beam 89 and a single photodetector 86A.

By comparing FIG.44 to FIG.41, it may be seen that this nineteenth embodiment shown in FIG.44 does not have the optical path which extends horizontally from the beam splitter 208 in FIG.41. For this reason, the space occupied by the optical system within the optical information recording/reproducing apparatus and the number of required parts are further reduced in this embodiment when compared to the eighteenth embodiment. In other words, both the size and cost of the optical information recording/reproducing apparatus in this embodiment can further be reduced when compared to those of the eighteenth embodiment.

In addition, if the photodetector 86A is adjusted to detect a predetermined focal error signal FES, it is possible to employ a structure that would automatically receive the third through sixth light beams 91c through 91f by the corresponding light receiving parts E<sub>1</sub>, E<sub>2</sub>, F<sub>1</sub> and F<sub>2</sub> of the second through fifth photodetectors 86Ab-1 through 86Ac-2. Hence, there is an additional advantage in that no adjustment is required in this case for the detection of the tracking error signal TES and the magneto-optic signal RF.

Of course, independent Wollaston prism and composite prism may be used in place of the integral part 90 which integrally comprises the Wollaston prism 92 and the composite prism 85. In other words, the independent Wollaston prism may be provided at a position to confront the back of the composite prism with a gap formed therebetween.

Further, the present invention is not limited to these embodiments, but various variations and modifications may be made without departing from the scope of the present invention.

**Claims**

1. An optical information recording/reproducing apparatus which records information on and/or reproduces information from an optical recording medium and detects a focal error based on a reflected light beam from the optical recording medium, characterized in that said optical information recording/reproducing apparatus comprises:

an optical element (15, 15A, 25, 25A, 85, 85A, 95, 95A, 105, 105A, 105B, 35, 45, 55) deflecting a part of the reflected light beam to at least two positions excluding a central part of the reflected light beam; and

photodetector means (16, 26, 36, 56, 66, 216, 216A, 217, 217A) including a plurality of photodetectors for respectively detecting the deflected parts of the reflected light beam and outputting detection outputs,

said focal error being detected based on the detection outputs of said photodetector means.

2. The optical information recording/reproducing apparatus as claimed in claim 1, characterized in that said optical element (15, 15A, 25, 25A, 85, 85A, 95, 95A, 105, 105A, 105B, 35, 45, 55) comprises a composite prism (15, 15A, 25, 25A, 35, 45, 55) including a plurality of tapered deflecting parts (15a, 15b, 25a, 25b, 35a, 35b, 45a, 45b, 55a, 55b), the part of the reflected light beam excluding the central part of the reflected light beam being deflected to at least two positions by said deflecting parts.

3. The optical information recording/reproducing apparatus as claimed in claim 1 or 2, characterized in that said optical element (15, 15A, 25, 25A, 35, 45, 55) includes a non-deflecting part (15c, 15cA, 25c, 25cA, 35c, 45c, 55c) which does not deflect the central part of the reflected light beam.

4. The optical information recording/reproducing apparatus as claimed in claim 3, characterized in that said non-deflecting part (15c, 15cA, 25c, 25cA, 35c, 45c, 55c) of said optical element (15, 15A, 25, 25A, 35, 45, 55) is selected from a group of parts consisting of:

a part (15c, 25c, 55c) which has a flat surface approximately perpendicular to an optical axis of the reflected light beam,

a part (35c, 45c) which has a curved surface having a slight curvature with respect to the optical axis of the reflected light beam, and

a part (15cA, 25cA) which absorbs or re-

flects the central part of the reflected light beam.

5. The optical information recording/reproducing apparatus as claimed in claim 1, characterized in that said optical element (15, 15A, 25, 25A, 85, 85A, 95, 95A, 105, 105A, 105B, 35, 45, 55) comprises a hologram optical element (85, 85A, 95, 95A, 105, 105A, 105B) including a plurality of first deflecting parts (85a, 85b, 95a, 95b, 105a-105d, 105cA, 105dA, 105aB-105dB) formed with hologram patterns, the part of the reflected light beam excluding the central part of the reflected light beam being deflected to at least two positions by said first deflecting parts.

6. The optical information recording/reproducing apparatus as claimed in claim 5, characterized in that said hologram optical element (85, 85A, 95, 95A) includes a non-deflecting part (85c, 85cA, 95c, 95cA) which does not deflect the central part of the reflected light beam.

7. The optical information recording/reproducing apparatus as claimed in claim 6, characterized in that said non-deflecting part (85c, 85cA, 95c, 95cA) of said hologram optical element ((85, 85A, 95, 95A) is selected from a group of parts consisting of:

a part (85c, 95c) which has a surface approximately perpendicular to an optical axis of the reflected light beam, and

a part (85cA, 95cA) which absorbs or blocks the central part of the reflected light beam.

8. The optical information recording/reproducing apparatus as claimed in claim 5, characterized in that said hologram optical element (105, 105A, 105B) further includes second deflection parts (105c, 105d, 105cA, 105dA, 105cB, 105dB) formed with hologram patterns at a central part of said hologram optical element, a part of the reflected light beam used for detecting a tracking error being deflected by said second deflection parts to at least two positions which are different from said two positions to which the reflected light beam is deflected by said first deflection parts.

9. The optical information recording/reproducing apparatus as claimed in claim 5, characterized in that there is further provided a photodetector (217) arranged at a position shifted in a predetermined direction from a center of an optical axis of an optical system

which supplies the reflected light beam to said hologram optical element (105B), said photodetector receiving the reflected light beam obtained via said hologram optical element.

10. An optical information recording/reproducing apparatus which records information on and/or reproduces information from an optical recording medium and detects a tracking error and a focal error based on a reflected light beam from the optical recording medium, characterized in that said optical information recording/reproducing apparatus comprises:

beam splitter means (35, 45, 55, 75) for splitting the reflected light beam into at least one first beam which is used for detecting the tracking error and at least two second beams which are used for detecting the focal error; and

photodetector means (36, 56, 66) including a first photodetector (36c, 56c, 66c, 66f, 66i) which detects the first beam at a position other than an image formation point of the first beam, and second photodetectors (36a, 36b, 56a, 56b, 66a, 66b, 66d, 66e, 66g, 66h) for detecting the second beams approximately at image formation points of the second beams.

11. The optical information recording/reproducing apparatus as claimed in claim 10, characterized in that there is further provided: means for detecting the tracking error according to the push-pull technique based on outputs of the first photodetector (36c, 56c, 66c, 66f, 66i), and means for detecting the focal error according to the Foucault technique based on outputs of the second photodetectors (36a, 36b, 56a, 56b, 66a, 66b, 66d, 66e, 66g, 66h).

12. The optical information recording/reproducing apparatus as claimed in claim 10 or 11, characterized in that said beam splitter means (35, 45, 55) comprises a composite prism (35, 45, 55) which splits the reflected light beam into the first and second beams and deflects at least the second beams to the second photodetectors (36a, 36b, 56a, 56b, 66a, 66b, 66d, 66e, 66g, 66h).

13. The optical information recording/reproducing apparatus as claimed in claim 10 or 11, characterized in that said beam splitter means (75) comprises a hologram optical element (75) which splits the reflected light beam into the first and second beams and deflects at least the second beams to the second photodetectors (36a, 36b, 56a, 56b, 66a, 66b, 66d, 66e, 66g, 66h).

14. The optical information recording/reproducing apparatus as claimed in claim 12 or 13, characterized in that the first and second photodetectors (36c, 66c, 66f, 66i, 36a, 36b, 66a, 66b, 66d, 66e, 66g, 66h) of said photodetector means (36, 66) are respectively provided on a plane which is approximately perpendicular to an optical axis of the reflected light beam and includes image formation points of each of the second beams.

15. The optical information recording/reproducing apparatus as claimed in claim 12 or 13, characterized in that the first photodetector (56c) of said photodetector means (56) is provided on a plane which is approximately perpendicular to an optical axis of the reflected light beam and excludes an image formation point of each first beam, and said second photodetectors (56a, 56b) of the photodetector means are provided on a plane which is approximately perpendicular to the optical axis of the reflected light beam and includes image formation points of each of the second beams.

16. An optical information recording/reproducing apparatus which records information on and/or reproduces information from an optical recording medium and detects a focal error and a tracking error based on a reflected light beam from the optical recording medium, characterized in that said optical information recording/reproducing apparatus comprises:

beam splitter means (85) for splitting the reflected light beam into first through fourth light beams (87a-87d) which propagate generally in a predetermined direction; and

photodetector means (86) for detecting the focal error in response to the first and second light beams, and for detecting the tracking error in response to the third and fourth light beams.

17. The optical information recording/reproducing apparatus as claimed in claim 16, characterized in that said photodetector means (86) comprises a first photodetector (86a) including four light receiving parts for receiving the first and second light beams (87a, 87b), and second photodetectors (86b, 86c) including light receiving parts for receiving the third and fourth light beams (87c, 87d), said first and second photodetectors being provided on a single plane.

18. The optical information recording/reproducing apparatus as claimed in claim 16 or 17, characterized in that said beam splitter means (85) comprises a composite prism (85) having a back surface which is approximately perpendicular to a traveling direction of the incoming reflected light beam and inclined first through fourth emission surfaces (85a-85d), said first and second emission surfaces being respectively inclined by angles  $\alpha_1$  and  $\alpha_2$  relative to the back surface in mutually opposite directions, said third and fourth emission surfaces being respectively inclined by angles  $\alpha_3$  and  $\alpha_4$  relative to the back surface in mutually opposite directions and forming a mountain shape between said first and second emission surfaces, said first and third emission surfaces being inclined in the same direction, said second and fourth emission surface being inclined in the same direction, where  $\alpha_1 < \alpha_3$  and  $\alpha_2 < \alpha_4$ .

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19. An optical information recording/reproducing apparatus which records an information signal on and/or reproduces the information signal from an optical recording medium and detects a tracking error, a focal error, the information signal and an address signal based on a reflected light beam from the optical recording medium, characterized in that said optical information recording/reproducing apparatus comprises:

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beam splitter means (90) for splitting the reflected light beam into first through sixth light beams (91a-91f) which propagate generally in a predetermined direction; and

30

photodetector means (86A) for detecting the focal error in response to the first and second light beams (91a, 91b), and for detecting the tracking error, the information signal and the address signal in response to the third through sixth light beams (91c-91f).

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20. The optical information recording/reproducing apparatus as claimed in claim 19, characterized in that said photodetector means (86A) comprises a first photodetector (86Aa) including four light receiving parts for receiving the first and second light beams (91a, 91b), second through fifth photodetectors (86Ab-1 - 86Ac-2) including light receiving parts for respectively receiving the third through sixth light beams (91c-91f), said first through fifth photodetectors being provided on a single plane.

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21. The optical information recording/reproducing apparatus as claimed in claim 19 or 20,

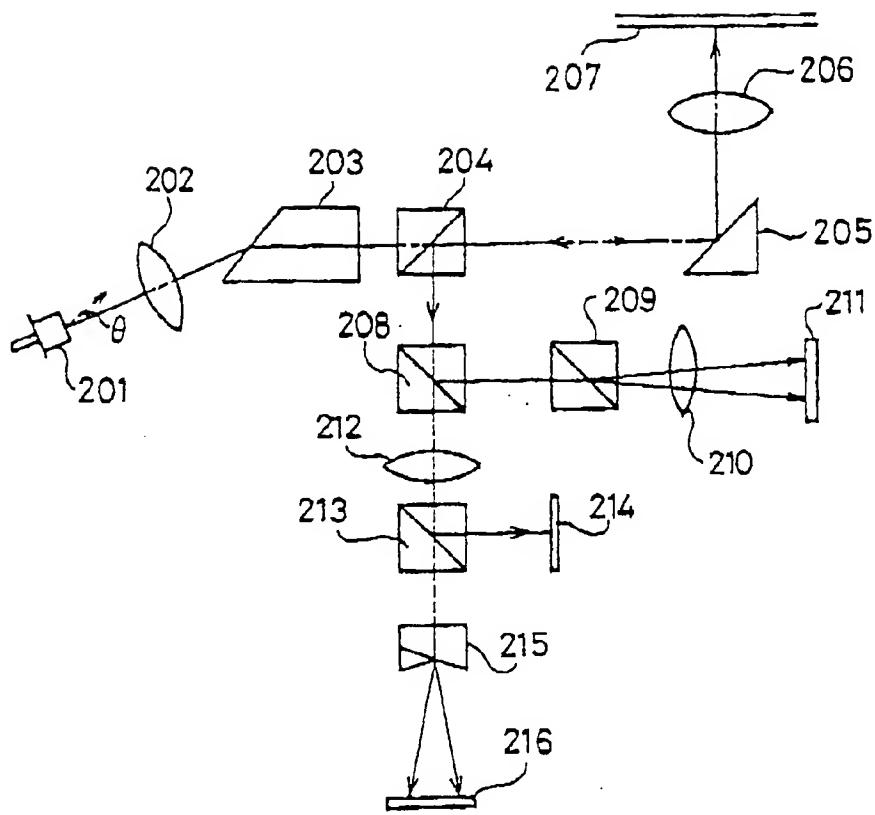
characterized in that said beam splitter means (90) comprises:

a composite prism (85) having a back surface which is approximately perpendicular to a traveling direction of the incoming reflected light beam and inclined first through fourth emission surfaces (85a-85d), said first and second emission surfaces being respectively inclined by angles  $\alpha_1$  and  $\alpha_2$  relative to the back surface in mutually opposite directions, said third and fourth emission surfaces being respectively inclined by angles  $\alpha_3$  and  $\alpha_4$  relative to the back surface in mutually opposite directions and forming a mountain shape between said first and second emission surfaces, said first and third emission surfaces being inclined in the same direction, said second and fourth emission surface being inclined in the same direction, where  $\alpha_1 < \alpha_3$  and  $\alpha_2 < \alpha_4$ ; and

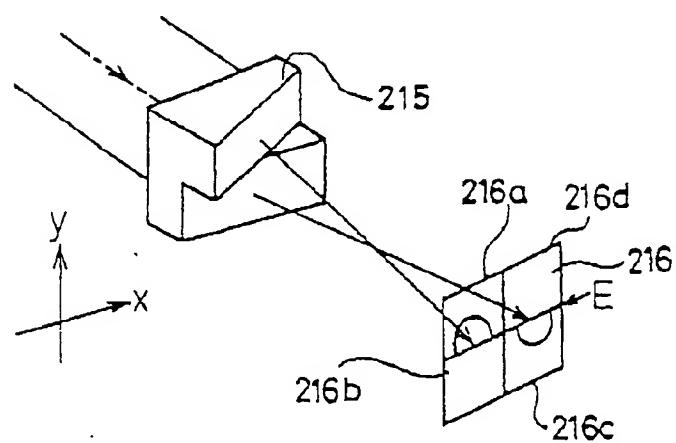
a Wollaston prism (92) located immediately preceding said composite prism in the traveling direction of the incoming reflected light beam to confront the back surface at a position corresponding to the mountain shape so that said Wollaston prism splits the incoming reflected light beam in a direction in which a vertex of the mountain shape extends.

22. The optical information recording/reproducing apparatus as claimed in claim 21, characterized in that said composite prism (85) and said Wollaston prism (92) are integrally connected.

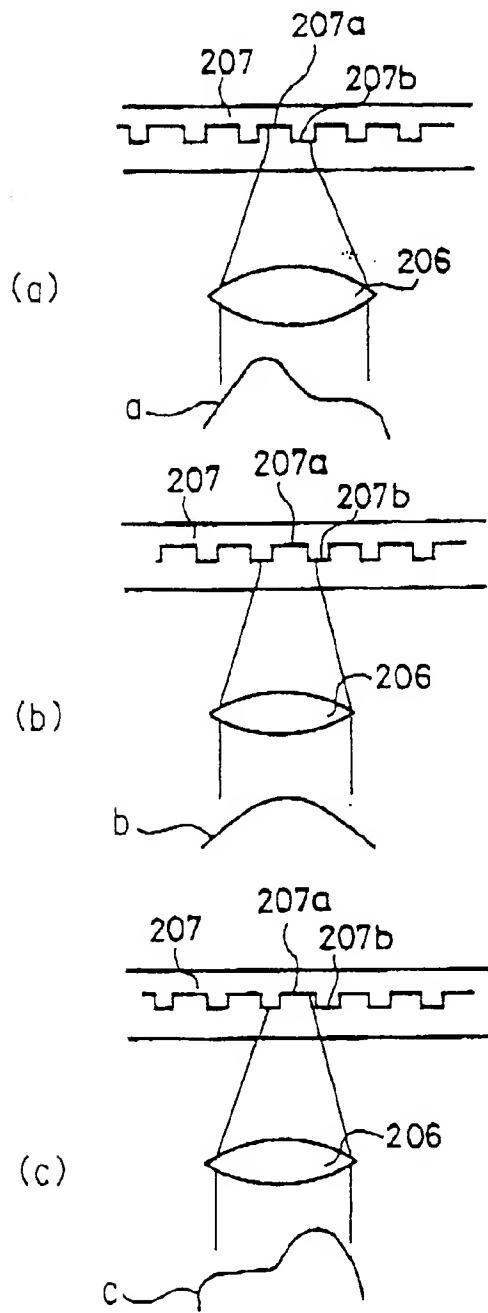
F I G. 1



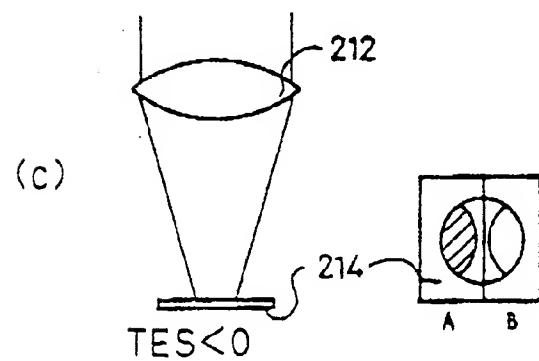
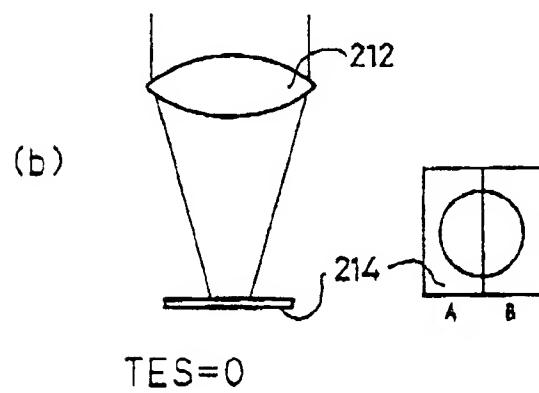
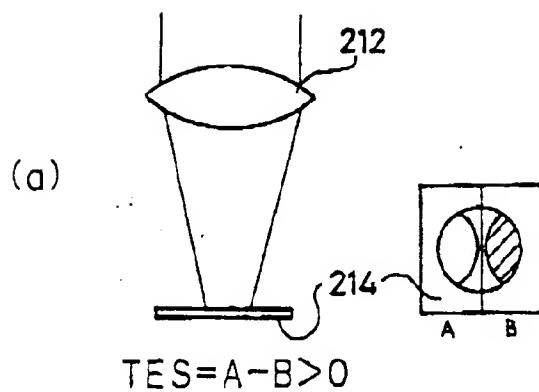
F I G. 4



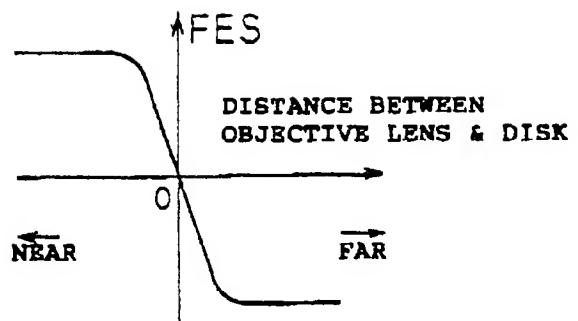
F I G. 2



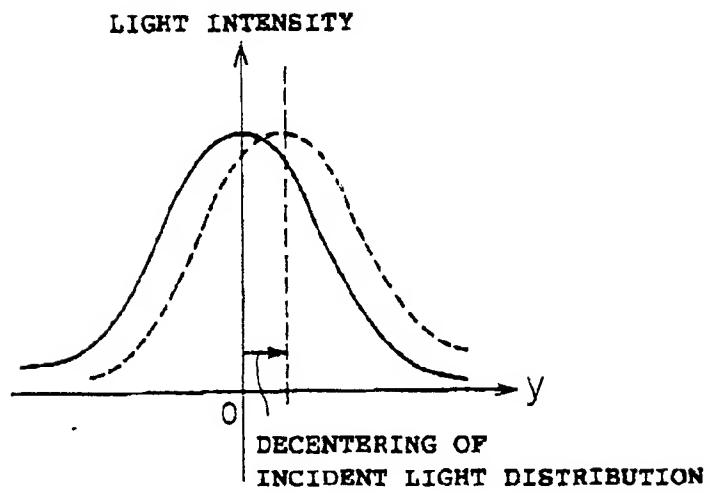
F I G. 3



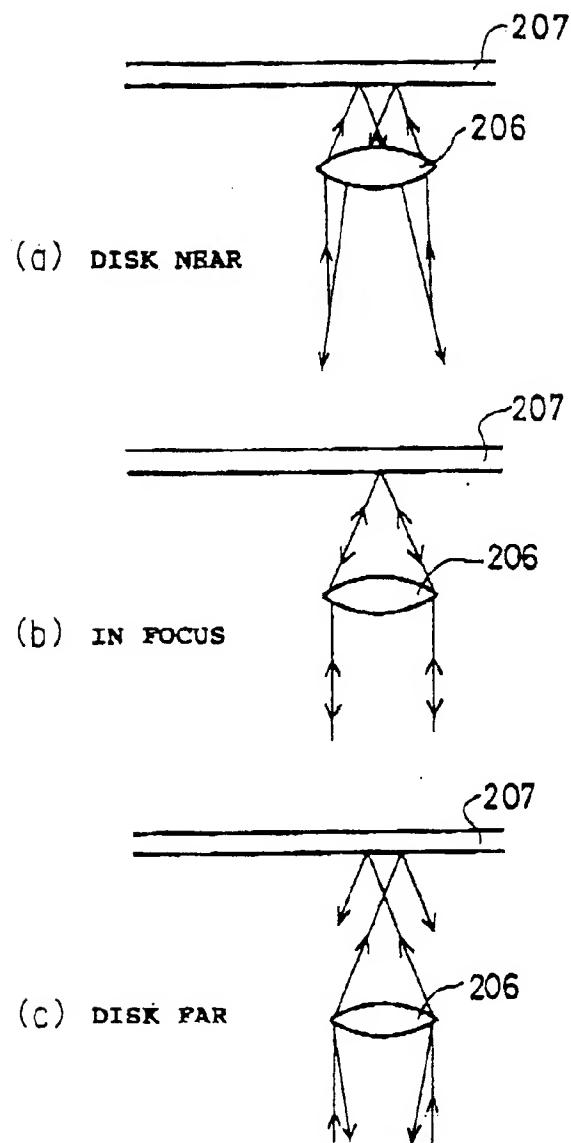
F I G. 5



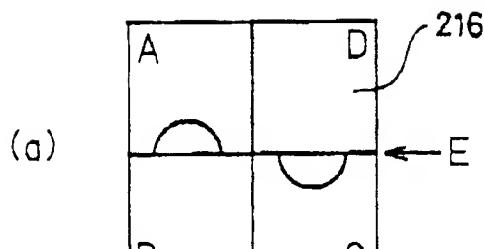
F I G. 8



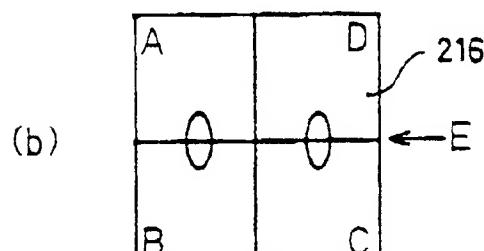
F I G. 6



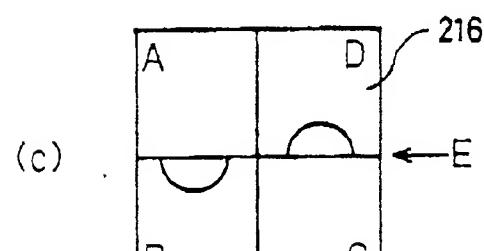
F I G. 7



$$FES = (A - B) + (C - D) > 0$$

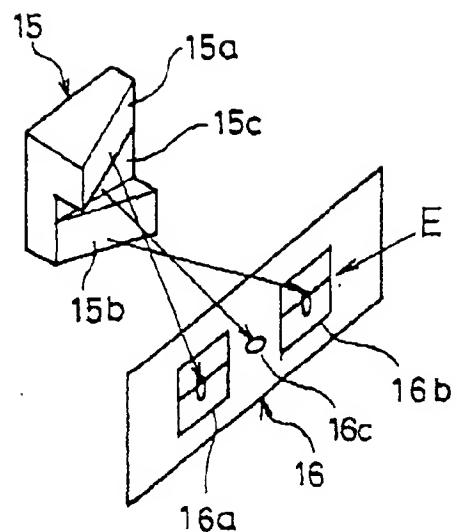


$$FES = 0$$

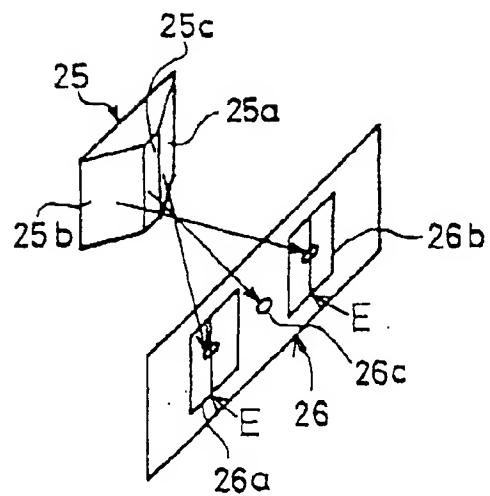


$$FES < 0$$

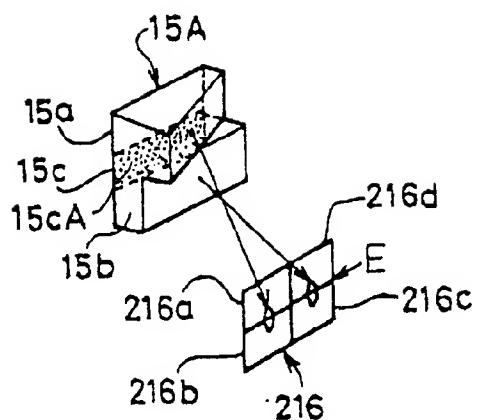
F I G. 9



F I G. 10



F I G. 1 1



F I G. 1 2

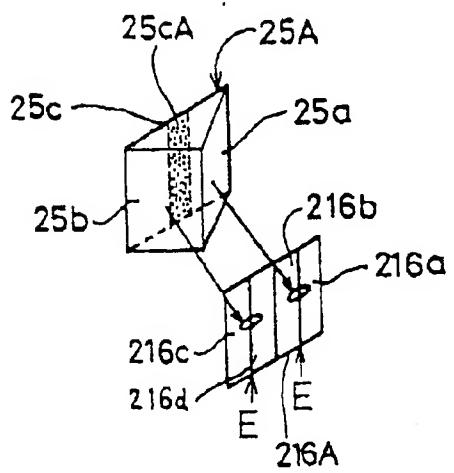


FIG. 13

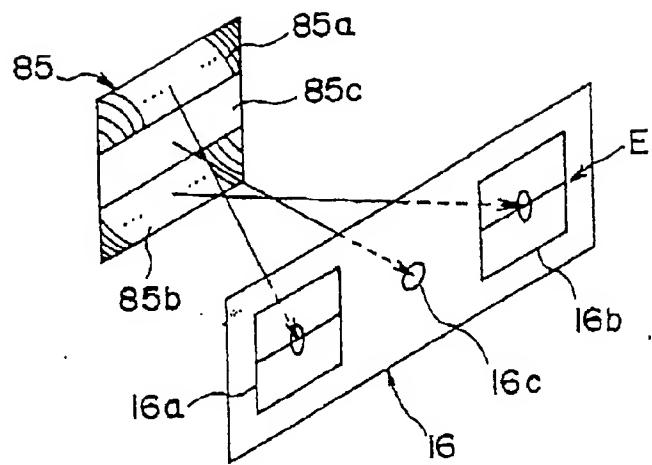


FIG. 14

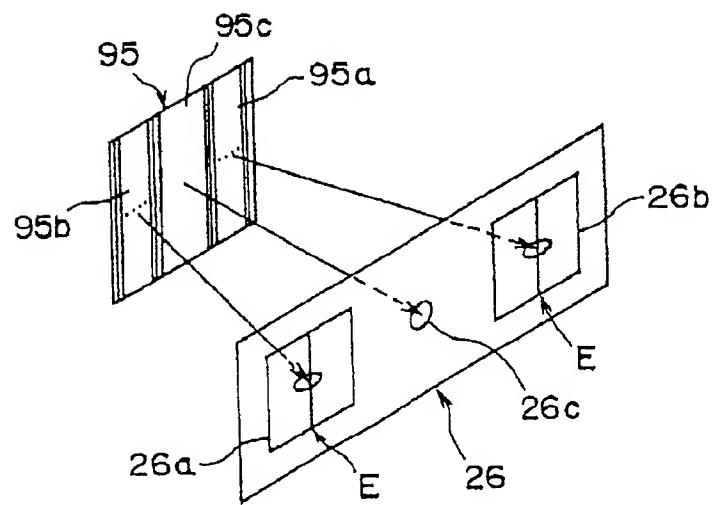


FIG. 15

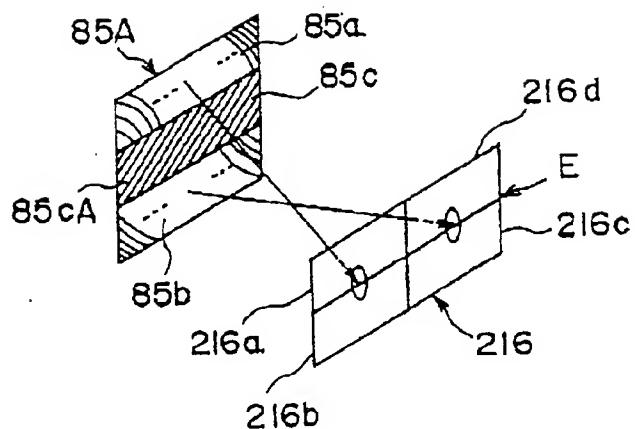


FIG. 16

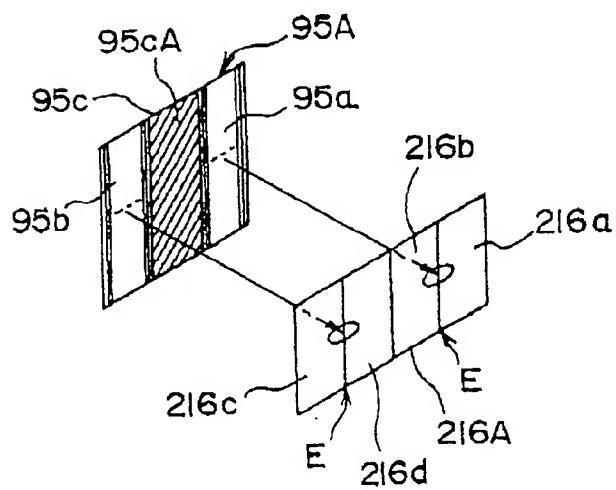


FIG. 17

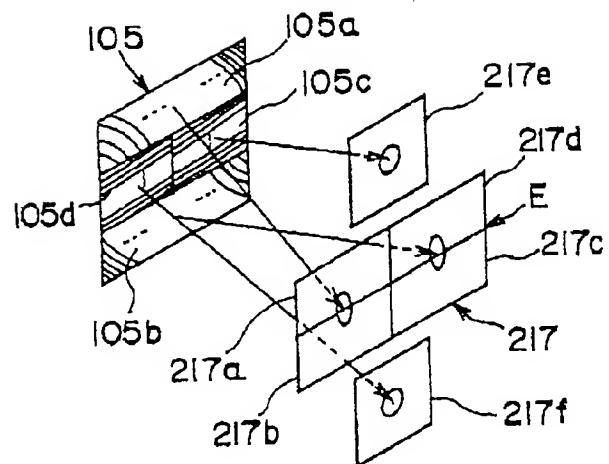


FIG. 18

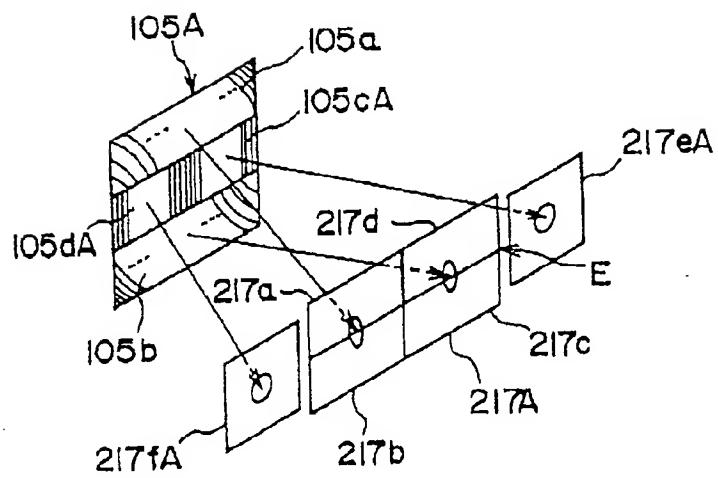


FIG. 19

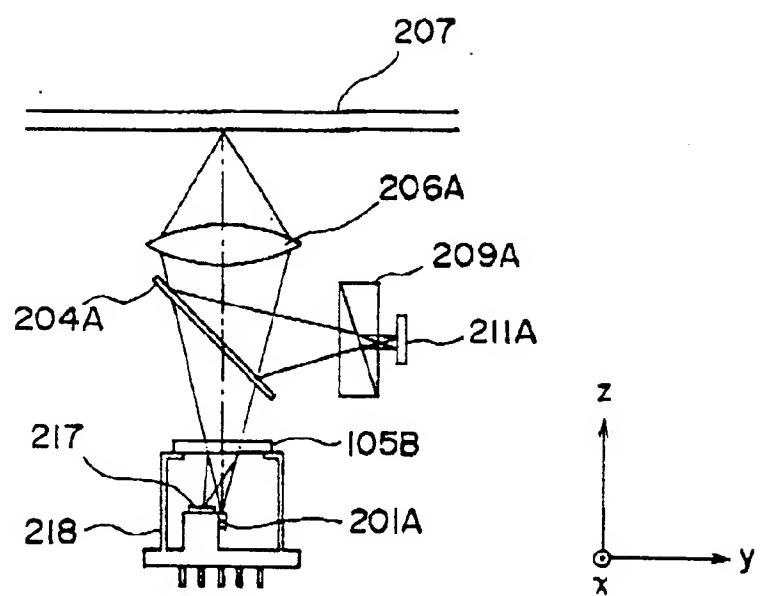


FIG. 20

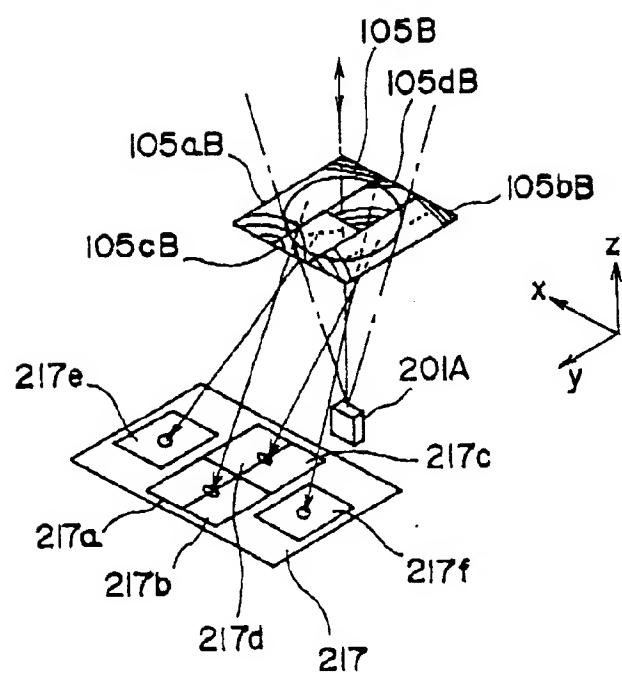


FIG. 21

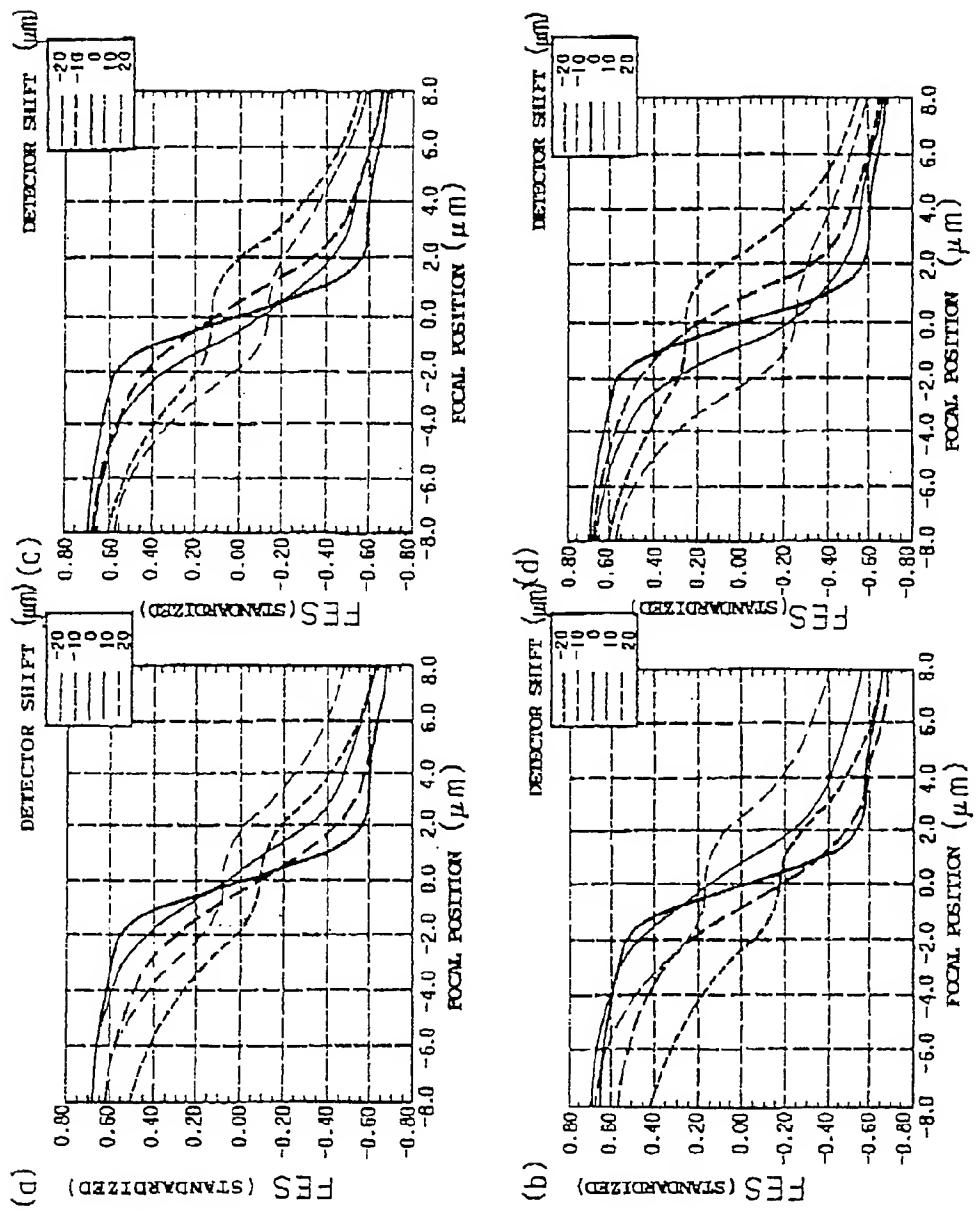


FIG. 22

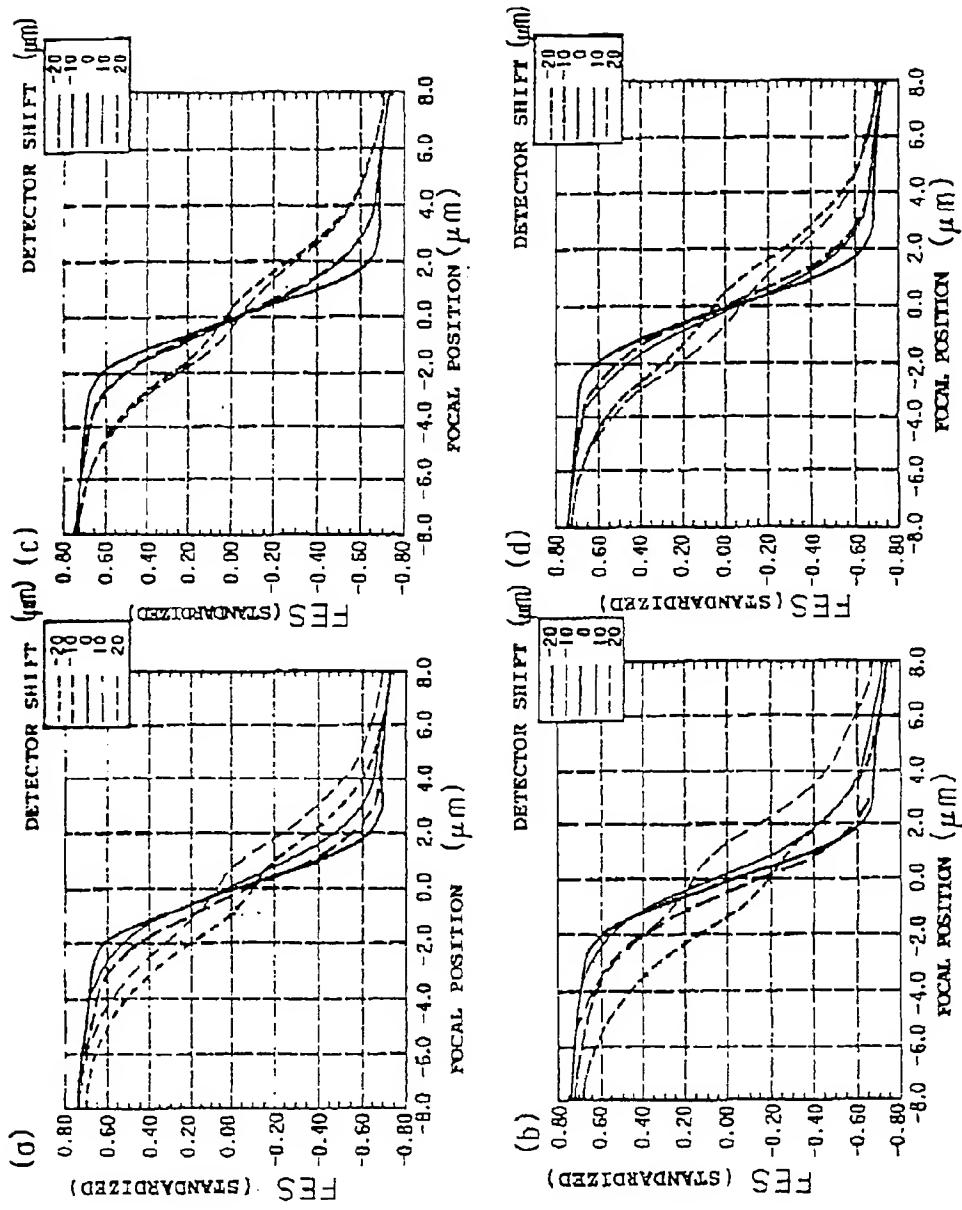


FIG. 23

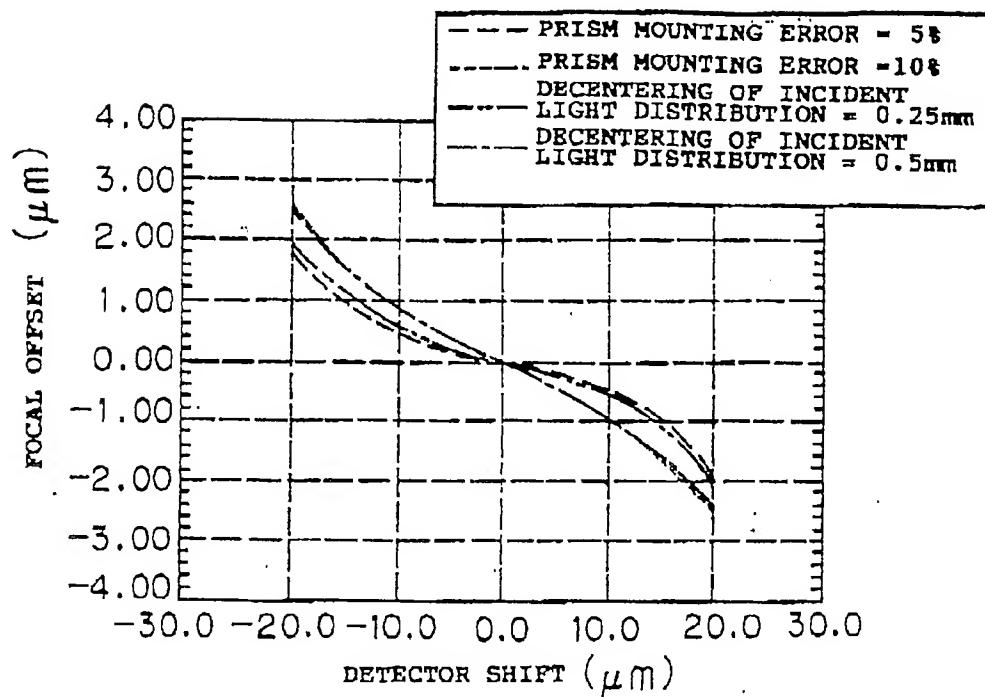


FIG. 24

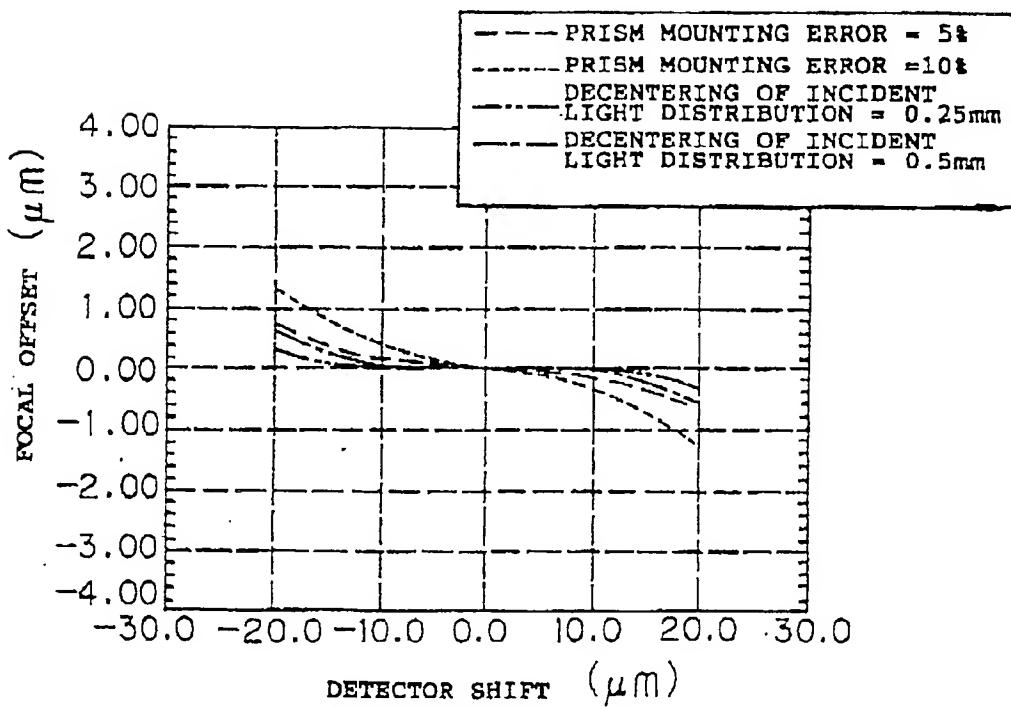


FIG. 25

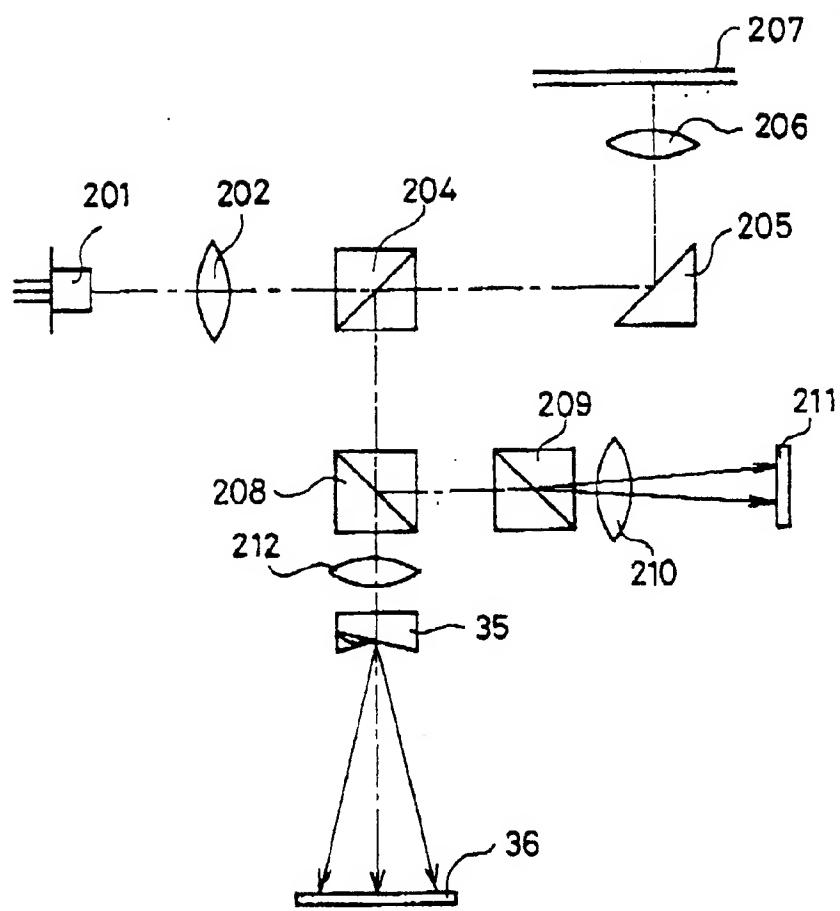


FIG. 26

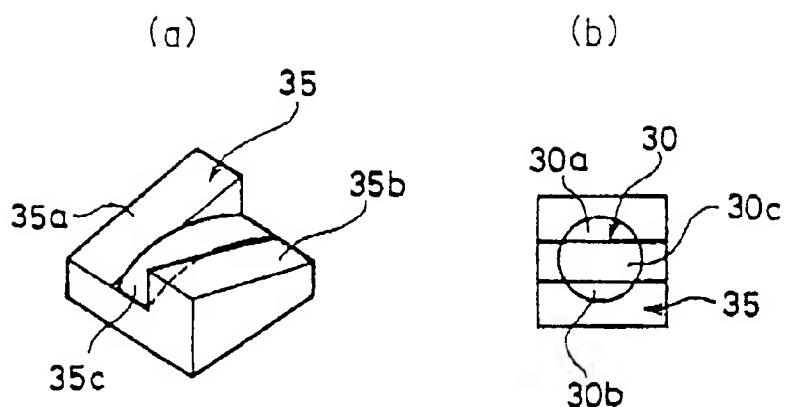


FIG. 28

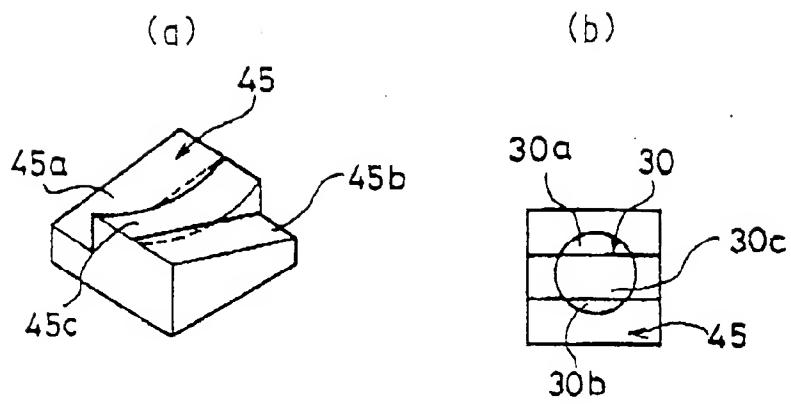


FIG. 27

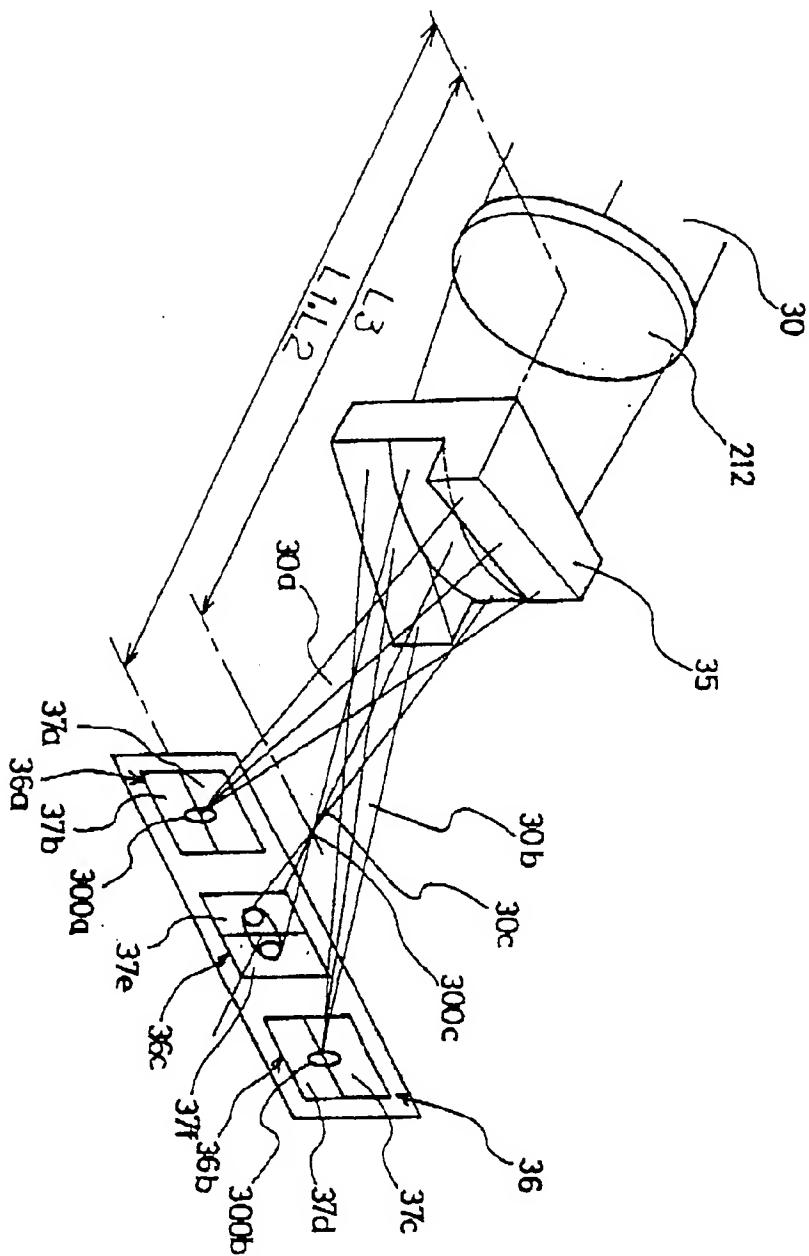


FIG. 29

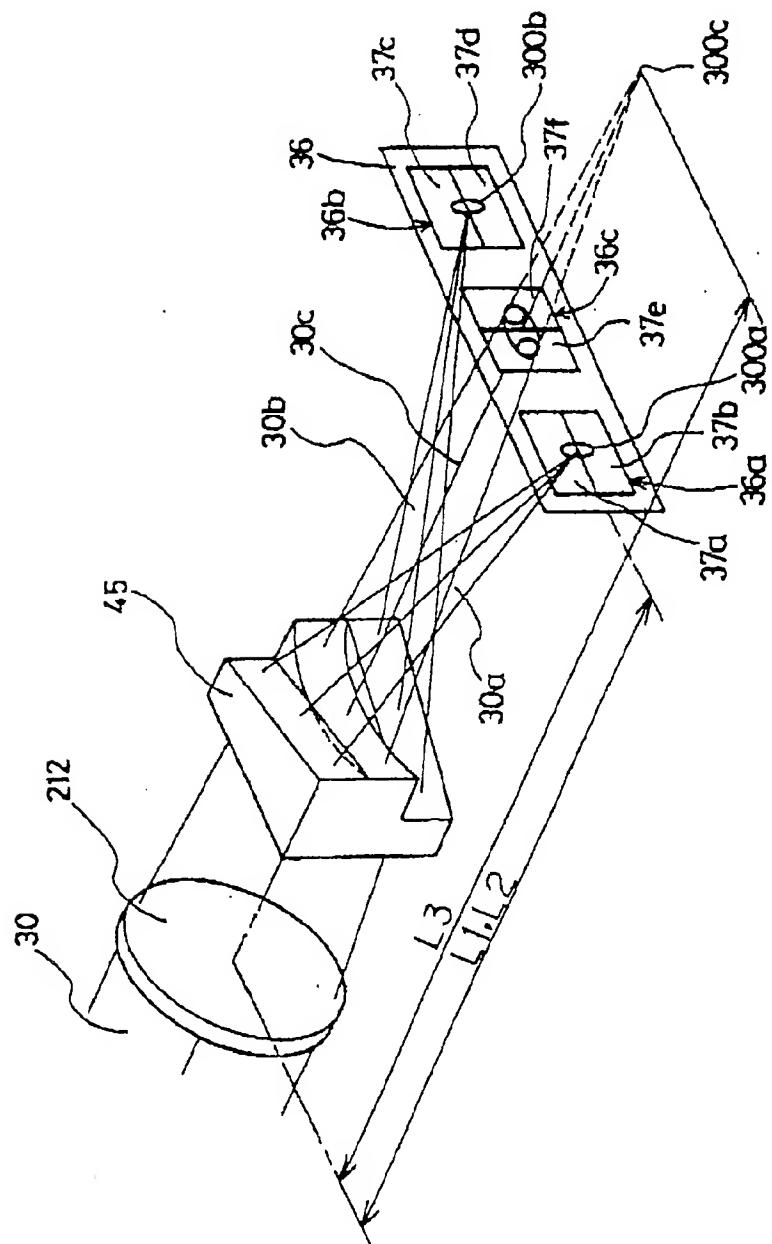


FIG. 30

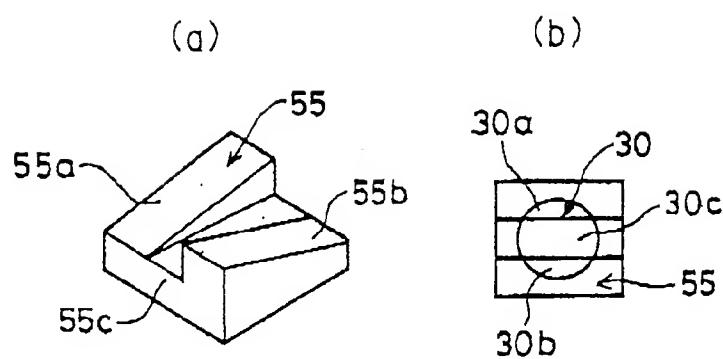


FIG. 32

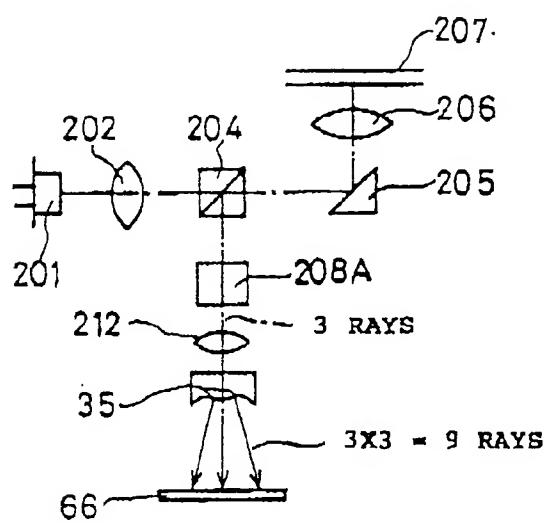


FIG. 31

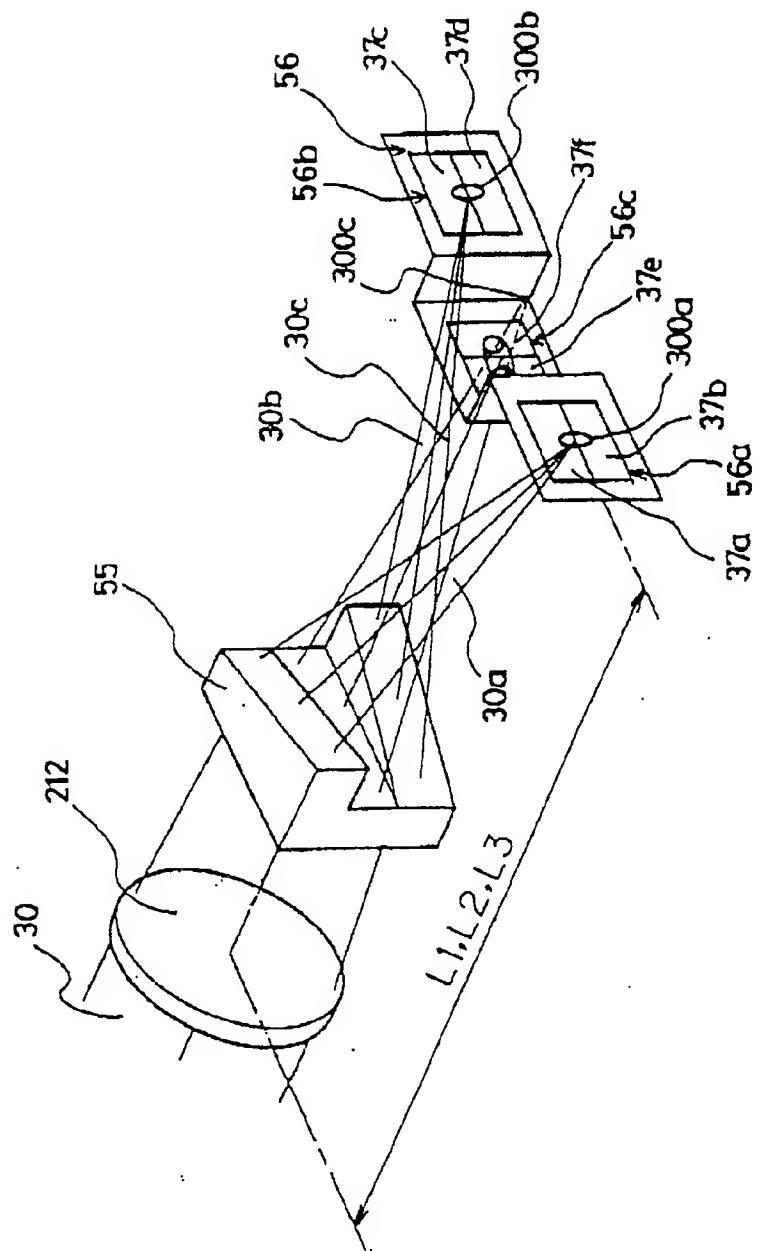


FIG. 33

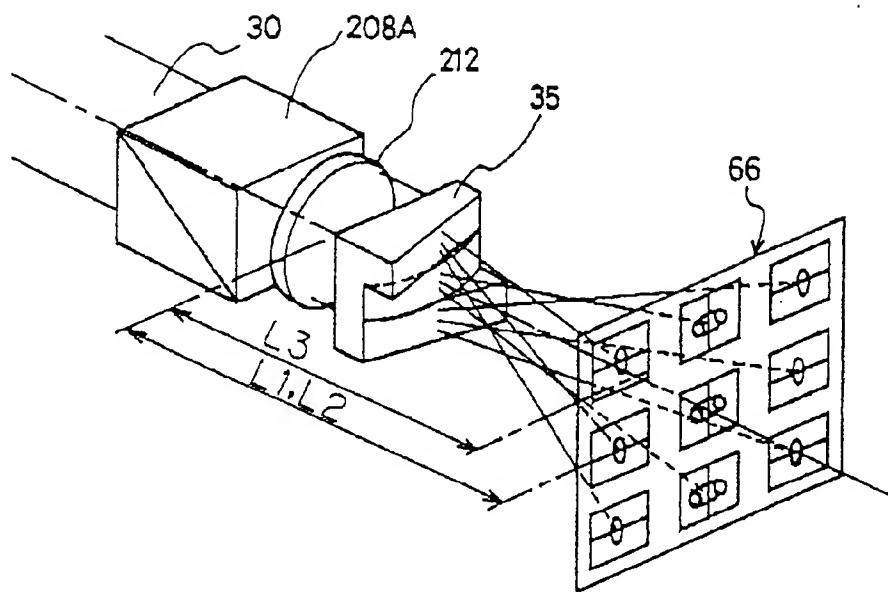


FIG. 34

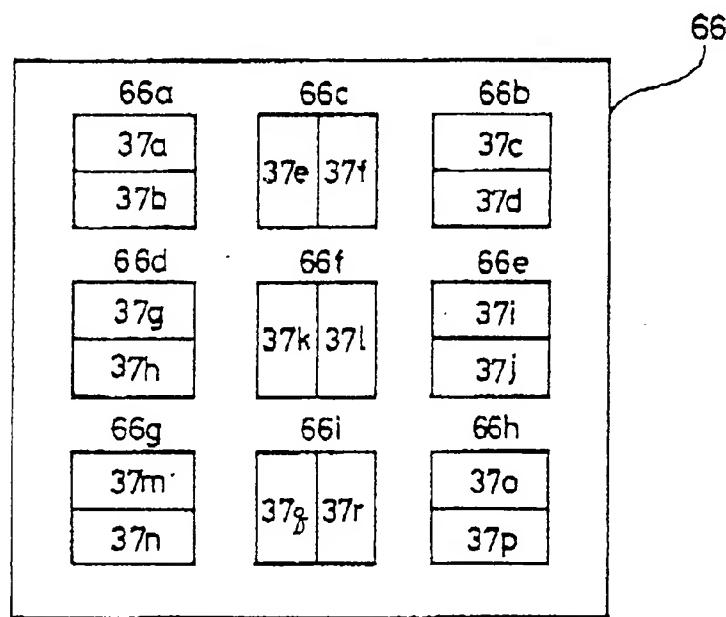


FIG. 35

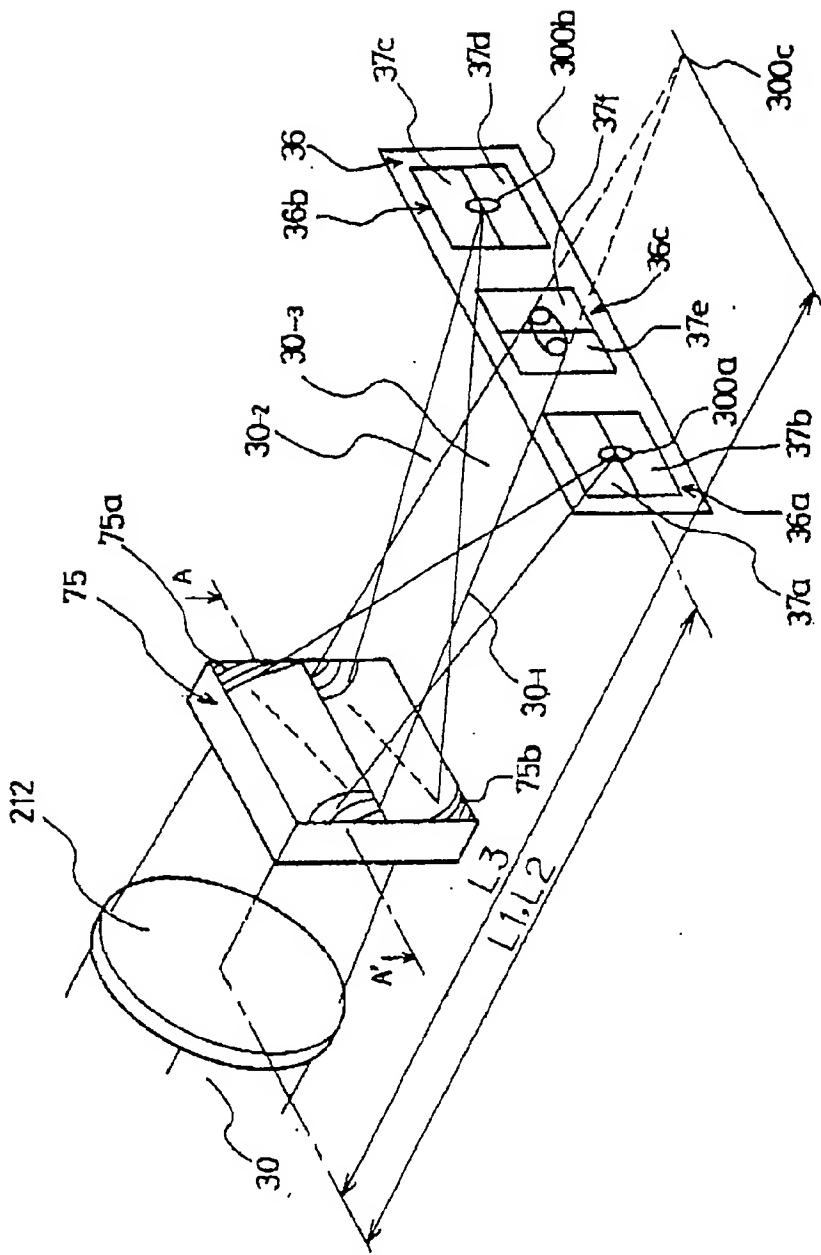


FIG. 36

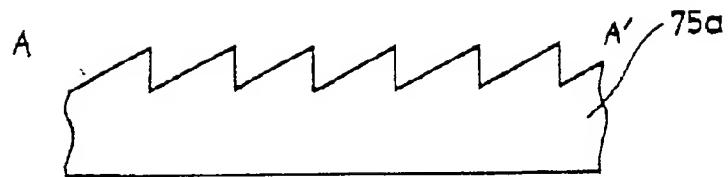


FIG. 37

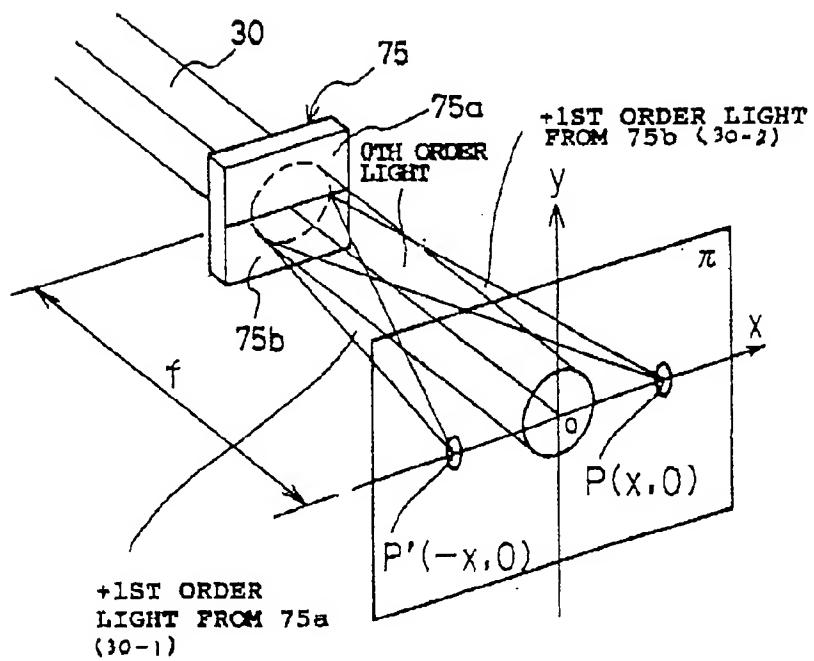


FIG. 38

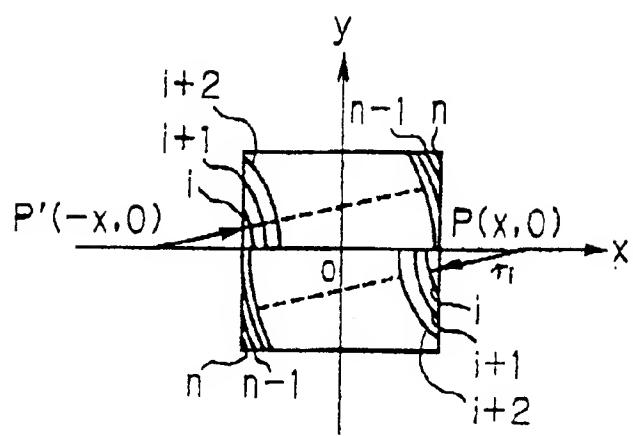


FIG. 39

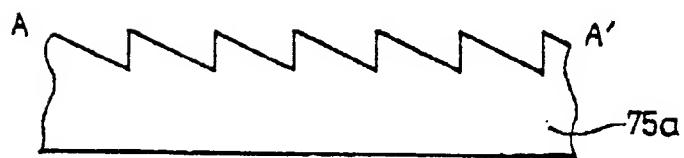


FIG. 40

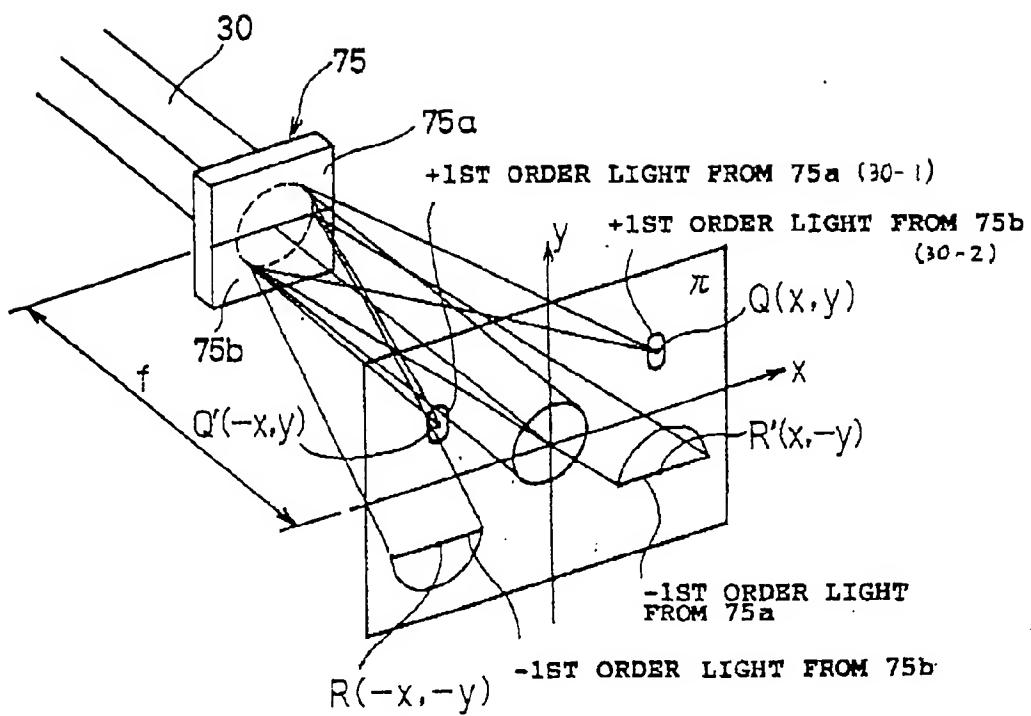


FIG. 41

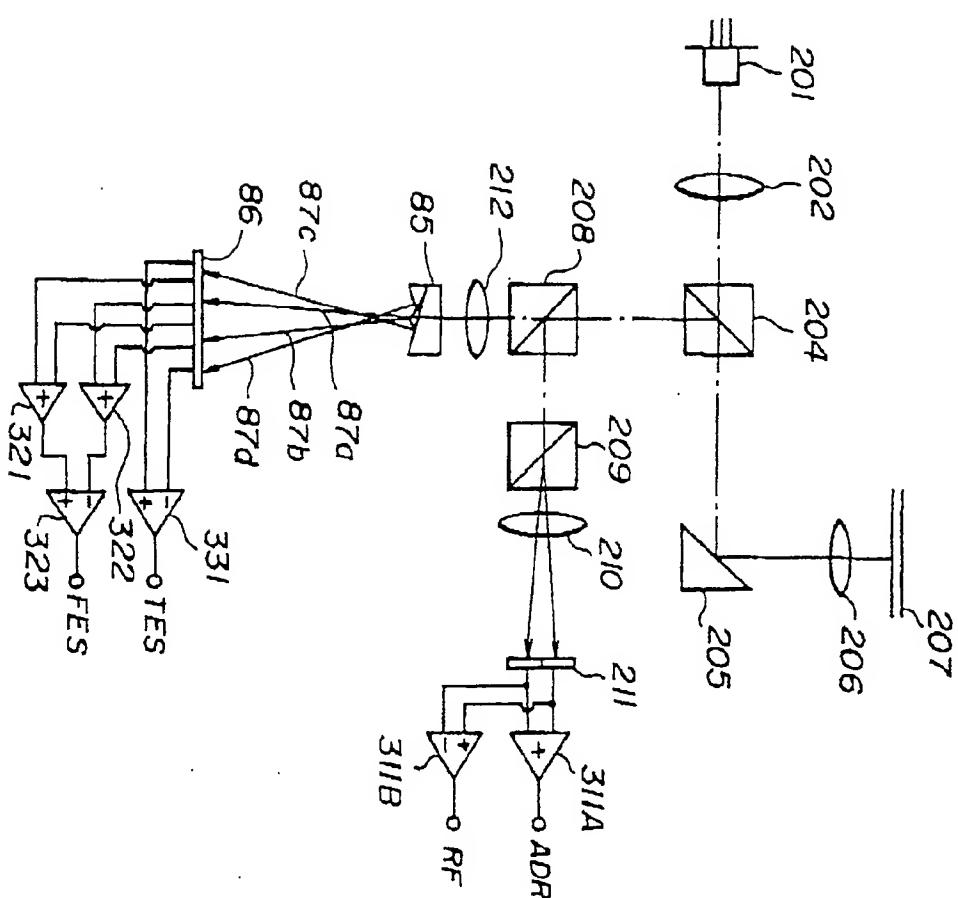


FIG. 42

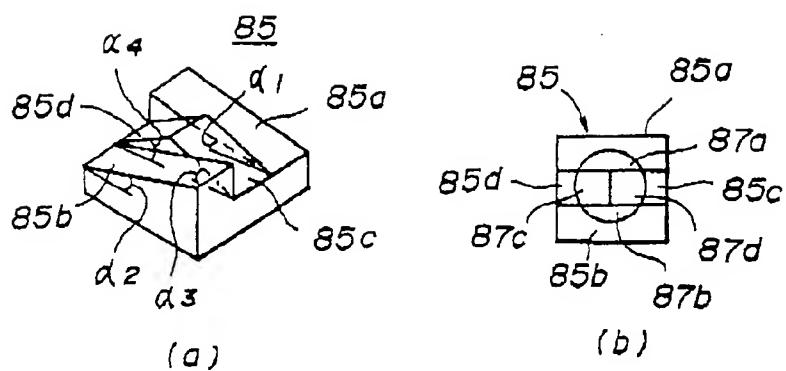


FIG. 43

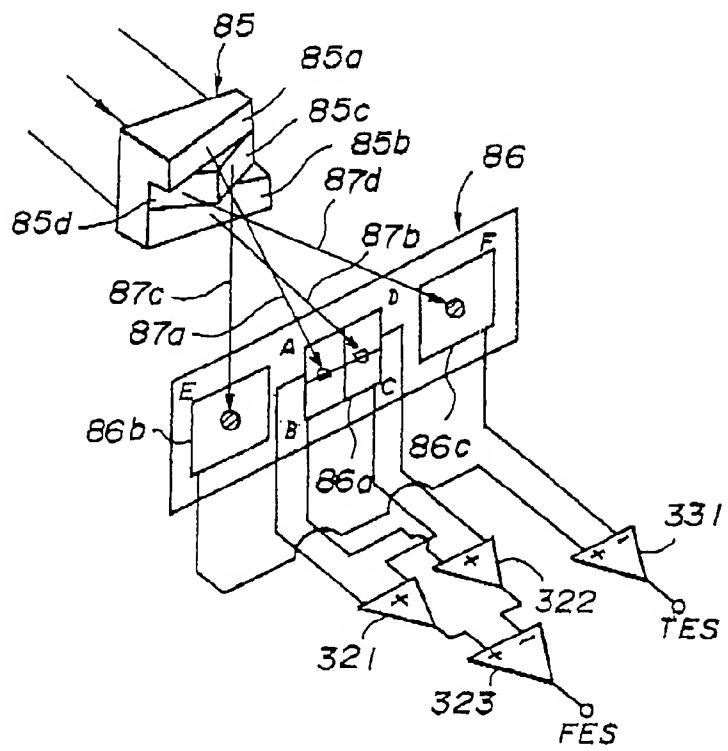


FIG. 44

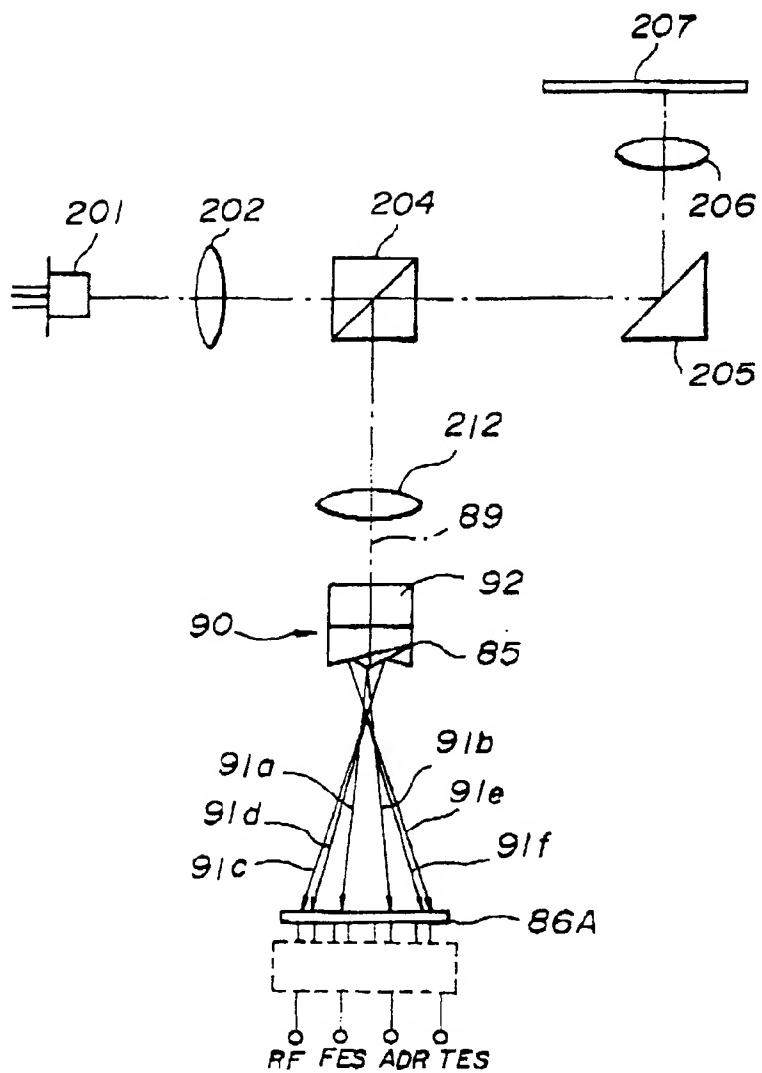


FIG. 45

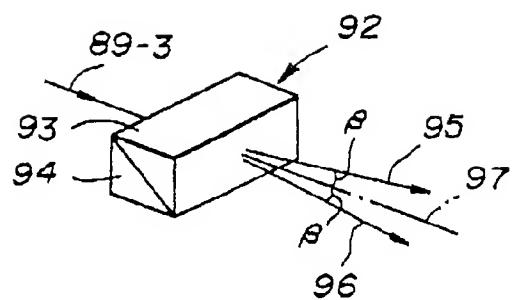


FIG. 46

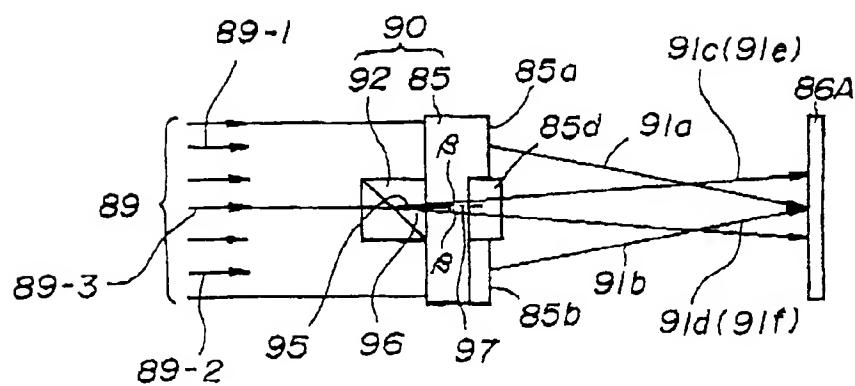
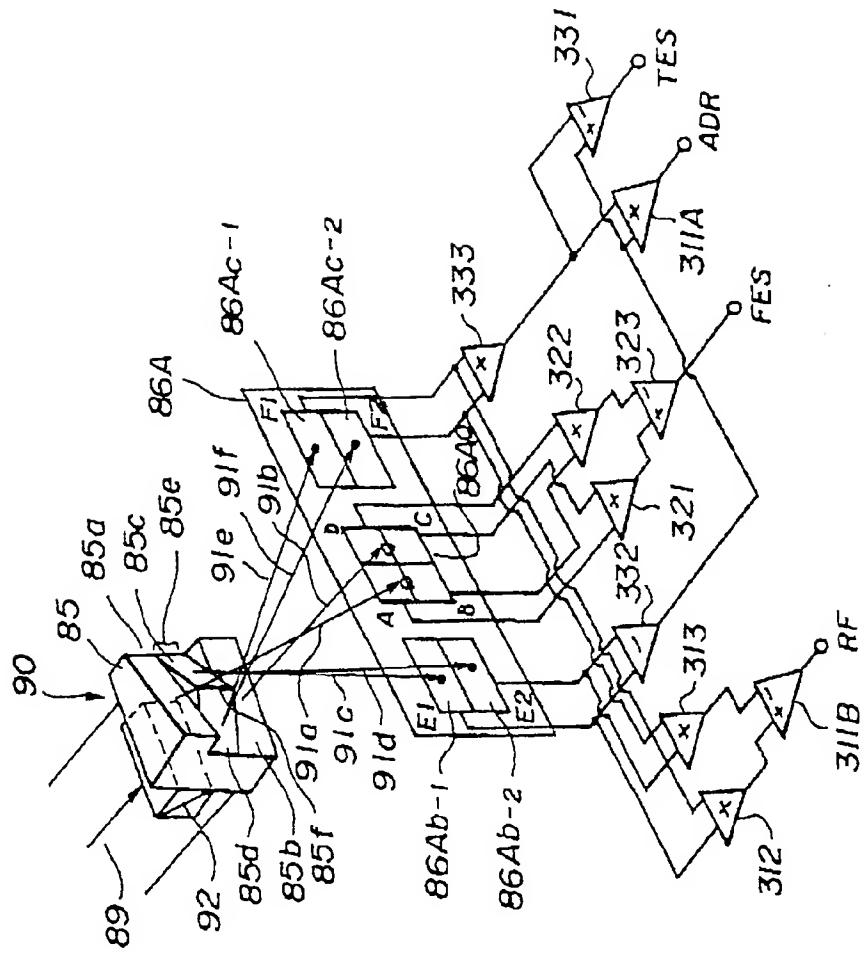


FIG. 47





European Patent  
Office

## EUROPEAN SEARCH REPORT

Application Number  
EP 94 10 9460

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
X	PATENT ABSTRACTS OF JAPAN vol. 13, no. 59 (P-826) 10 February 1989 & JP-A-63 249 942 (MATSUSHITA) 17 October 1988 * abstract *---	1-4	G11B7/09 G11B7/135
X	PATENT ABSTRACTS OF JAPAN vol. 15, no. 395 (P-1260) 7 October 1991 & JP-A-03 157 821 (RICOH) 5 July 1991 * abstract *---	1-4	
X	US-A-5 105 411 (S. ISHIKA) * the whole document *---	1,10,11 16,19	
A	US-A-5 161 139 (A. INOUE, K. HOSHINO) * column 13, line 65 - column 14, line 66; figures 33,34 *---	16,17 5,8,9	
A	* figures 1,4,17 *---	1,2, 10-14,19	
X	US-A-4 873 678 (S. NAKAMURA, S. MACHIDA, T. TODA) * column 6, line 53 - column 8, line 19; figures 6-9 *-----	10	TECHNICAL FIELDS SEARCHED (Int.Cl.5) G11B
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
THE HAGUE		28 September 1994	Holubov, C
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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